The *De Subtilitate* of Girolamo Cardano

Edited by
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With an Introduction by
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Symbols and Abbreviations Used in the Translation

Girolamo Cardano, *De subtilitate libri XXI*... Paris: ex officina Michaelis Fezendat et Roberti Granjon. Cited in footnotes simply as "1550."

Girolamo Cardano, *De subtilitate libri XXI. Nunc demum ab ipso authore recogniti atque perfecti*. Basel: Ludovicus Lucius, 1554. Cited in footnotes simply as "1554."

Girolamo Cardano, *De subtilitate libri XXI. Ab authore plusquam mille locis illustrati, nonnullis etiam cum additionibus* . . . Basel: Officina Petrina, 1560. In the translation, "&280," for example, indicates the location of the start of page 280 of the 1560 edition. In footnotes, its page numbers are those specified as "280 (1560)."

These three editions are all currently available on the Internet (see Introduction, nn. 103, 104 and 105).

Occasional reference is made to the much later *Opera omnia* edition of 1663, in 10 volumes (Lyon: Charles Spon, Sumptibus I. A. Huguetan, & M. A. Ravaud). "*OO* 2" in footnotes, for instance, indicates volume 2 of this edition. But "*OO*" *without* roman numeral refers to its volume III, the volume containing *De Subtilitate*, with certain other works of Cardano.

References such as "[A]" in the translation indicate, in connection with explanatory footnotes, the beginning or end of passages of text which appear for the first time in the 1560 edition, or which appeared in the 1550 or 1554 editions but not in the 1560 recension.

"Nenci" in the notes refers to Elio Nenci's critical edition of the first eight books of *De subtilitate*: Girolamo Cardano, *De Subtilitate, Edizione critica (Tomo I, Libri I–VIII)*, ed. Elio Nenci (Rome: Franco Angeli, 2004).

"Castelli" refers to Bartolomeo Castelli, *Lexicon medicum Graeco-Latinum*. Geneva: Fratres de Tournes, 1746.

CAG indicates the *Commentaria in Aristotelem Graeca*, 23 volumes issued between 1882 and 1909 by the publisher Reimer.

CMG indicates *Corpus Medicorum Graeconem*, begun in Berlin in 1907.

L&S in the notes indicates the *Latin Dictionary* of C.T. Lewis and C. Short (Oxford: Clarendon Press, 1912).

Liddell&S indicates the *Greek-English Lexicon* of G. H. Liddell and R. Scott, 7th ed. (Oxford: Clarendon Press, 1890).

OCD indicates the *Oxford Classical Dictionary*, 3rd ed., ed. Simon Hornblower and Antony Spawforth (Oxford: Oxford University Press, 2003).

OED indicates the *Oxford English Dictionary*, 2nd ed., ed. J.A. Simpson and E.S.C. Weiner, 20 vols. (Oxford: Clarendon Press, 1989).

OLD indicates the *Oxford Latin Dictionary*, ed. P. G. W. Glare (Oxfored: Clarendon Press, 1997).

PG indicates the *Patrologia Graeca*, 161 volumes of writings of the Greek Christian Church Fathers, edited by J. P. Migne (1857–1866).

PL indicates the *Patrologia Latina*, 221 volumes of the writings of the Latin Christian Church Fathers, edited by J.P. Migne (1844–1865).

All other works are cited in the notes by author and short-title. Complete references are provided in the Bibliography.

In Ian Maclean, *Girolamo Cardano, De libris propriis* (2004), individual works by Cardano are numbered in chronological order of composition (with the number preceded by an "M"), thus for example: "M70." These designations have been used in the footnotes of the present translation to enable the interested reader immediately to consult the relevant details of any work of Cardano in Maclean's bibliographical account.

Wherever possible, editions of ancient works are cited from the Loeb Classical Library, now published by Harvard University Press. In footnotes, "Loeb, 3," for instance, refers to page 3 of the relevant work in the Loeb Classical Library. If the relevant work consists of more than one volume, as is the case of the *Natural history* of Pliny (10 vols), for example, the page numbers follow the particular volume no. So, for example, "Pliny, *Natural history*. 22. 3 (Loeb, 6: 295)," refers the reader to the sixth of the ten volumes in the Loeb Classical Library edition.

References to the page numbers of the present translation are not used.

Introduction

Girolamo Cardano (1501–1576), mathematician, astrologer, physician, natural philosopher, occult philosopher, and more, needs no introduction.[1] He achieved great fame in his own lifetime and has remained a prominent historical figure ever since. When his achievements in medicine and natural philosophy, and his assumptions about the occult, began to be superseded and rejected in the Scientific Revolution of the seventeenth century, his renown was maintained by his unique autobiography, *De vita propria*, written in the final year of his life and first seen through the press by Gabriel Naudé (1600–1653) in 1643. This most famous of Cardano's works came to be recognised, alongside the autobiographical

[1] On Cardano as an astrologer see Germana Ernst, *Religione, ragione e natura* (Milan: Franco Angeli, 1991), 191–219; eadem, "'Veritatis amor dulcissimus': Aspetti dell'astrologia in Cardano," in *Girolamo Cardano: Philosoph, Naturforscher, Arzt*, ed. E. Kessler (Wiesbaden: Harrassowitz, 1994), 158–84 (available in English as "'Veritatis amor dulcissimus': Aspects of Cardano's Astrology," in *Secrets of Nature: Astrology and Alchemy in Early Modern Europe*, ed. W. R. Newman and A. Grafton [Cambridge, MA: MIT Press, 2001], 39–68); and Anthony Grafton, *Cardano's Cosmos* (Cambridge, MA: Harvard University Press, 1999). On Cardano as a physician see Nancy Siraisi, *The Clock and the Mirror* (Princeton: Princeton University Press, 1997); and Markus Fierz, *Girolamo Cardano, 1501–1576: Physician, Natural Philosopher, Mathematician, Astrologer, and Interpreter of Dreams* (Boston: Birkhäuser, 1983). The best study of Cardano as a natural philosopher is provided in Ingo Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate (Munich: Fink, 2000). There is no major study of Cardano as a mathematician, even though there are many detailed studies of aspects of his mathematics. But see, for example, Øystein Ore, *Cardano, the Gambling Scholar* (Princeton: Princeton University Press, 1953); G. Gliozzi, s. v. "Cardano, Girolamo," in *Dictionary of Scientific Biography* (New York: Scribner, 1970–1990), 3: 64–67; and Girolamo Cardano, *Ars magna, or, The Rules of Algebra* (New York: Dover, 1993). On Cardano as an occult philosopher see Lynn Thorndike, *History of Magic and Experimental Science* (New York: Columbia University Press, 1923–1958), 5: 563–79; Silvia Parigi, ed., *La magia naturale nel Rinascimento: testi di Agrippa, Cardano, Fludd* (Turin: UTET, 1989); and Alfonso Ingegno, *Saggio sulla filosofia di Cardano* (Florence: La Nuova Italia, 1980). For a more general treatment see Marialuisa Baldi and Guido Canziano, eds., *Girolamo Cardano: Le opere, le fonti, la vita* (Milan: Franco Angeli, 1999).

writings of Desiderius Erasmus (*c.* 1466–1536), Benvenuto Cellini (1500–1575), and Michel de Montaigne (1533–1592), as the valuable beginnings of personal accounts of the life and times of significant figures.[2]

In spite of his enduring fame, however, and his undoubted importance in the history of Renaissance science, it seems fair to say that Cardano has failed to attract the scholarly attention that he deserves. To a large degree, this is no doubt due to the fact that Cardano's works have hardly ever been translated out of Cardano's difficult Latin. As Ian Maclean has wryly noted, Cardano's Latin "cannot be described as pellucid"; indeed it evidently drew complaints even from his contemporaries.[3] If we add to this what Anthony Grafton has described as the "length, variety, and technical density of Cardano's works," there can be little wonder that, as he notes, scholars have been deterred from approaching Cardano. Because of these difficulties, Grafton has predicted that,

> For years to come, all students of his work will be condemned to play the role of caterpillars exploring tiny portions of an enormous flowering garden.[4]

It is in a modest effort to speed Cardano studies along that this translation is offered here.

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[2] Hieronymus Cardanus, *De propria vita liber: ex bibliotheca Gab. Naudaei* (Paris: Jacob Villey, 1643). See Ian Maclean, ed., *Girolamo Cardano, De libris propriis: The Editions of 1544, 1550, 1557, 1562, with Supplementary Material* (Milan: Franco Angeli, 2004), 34. For a general study of Renaissance autobiography see Stephen Greenblatt, *Renaissance Self-fashioning from More to Shakespeare* (Chicago: University of Chicago Press, 1980). There is an elegant English translation of the *De vita propria*: Jerome Cardan, *The Book of My Life (De vita propria liber)*, trans. Jean Stoner (London: Dent, 1931). For more recent brief biographical treatments of Cardano see, for example, G. Gliozzi, s.v. "Cardano, Gerolamo," in *Dizionario biografico degli italiani* (Rome: Treccani, 1976), 19:759–63; and Siraisi, *The Clock and the Mirror*, 4–12. The major biography in English is still Henry Morley, *Jerome Cardan: The Life of Girolamo Cardano of Milan, Physician*, 2 vols. (London: Chapman and Hall, 1854); but see also W. G. Waters, *Jerome Cardan, a Biographical Study* (London: Lawrence & Bullen, 1898); James Eckman, *Jerome Cardan*, Supplement to the *Bulletin of the History of Medicine*, 7 (Baltimore: Johns Hopkins University Press, 1996); and Angelo Bellini, *Gerolamo Cardano e il suo tempo* (Milan: Franco Angeli, 1947). It is perhaps further testimony to his fame that he has even been the subject of a popular biography: Alan Wykes, *Doctor Cardano: Physician Extraordinary* (London: Muller, 1969). It is worth noting that although Cardano's philosophy was being superseded by the middle of the seventeenth century, this did not prevent the re-issue of the French translation of the *De subtilitate*, from Paris, in 1642.

[3] Maclean, ed., *Girolamo Cardano, De libris propriis*, 23. See also Kristian Jensen, "Cardano and his Readers in the Sixteenth Century," in *Girolamo Cardano*, ed. Kessler, 265–307.

[4] Grafton, *Cardano's Cosmos*, 17.

Of the flowers in Cardano's garden, the *De subtilitate* can perhaps be seen as the most prolific. Cardano himself included it among what he said were his four most widely-read works: *De fato*, *De arcanis aeternitatis*, *De subtilitate*, and *De rerum varietate*. Given that the first two of these circulated only in manuscript, and that the last one was merely a supplement to the *De subtilitate*, bringing together various materials which Cardano had originally excluded from the earlier work, because he had been unable to put them in order or "whip [them] into shape" [*castigare*],[5] it is easy to see that the *De subtilitate* was far and away Cardano's most widely distributed, widely read, and most frequently republished work (until it was overtaken, later, by the *De vita propria*).[6]

The *De subtilitate*, which one recent commentator has seen as marking "the beginning of a new phase in European culture," was nothing more or less than an attempt by Cardano to offer a complete compendium of natural philosophy.[7] It should not be supposed, however, that this was merely an attempt to set down in a single volume the natural philosophy of Aristotle, in the same way that Jean Fernel (1497–1558) had recently made a digest of the medical system of Galen, in his *De naturali parte medicinae*.[8] Geographical discoveries, changing attitudes to the so-called mixed mathematical sciences, technical progress, practical experience,

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[5] Cardan, *Book of my Life*, Chap. 45, 226; see also Maclean, ed., *Girolamo Cardano, De libris propriis*, 94.

[6] The details of all Cardano's publishing activities can be found in Maclean, ed., *Girolamo Cardano, De libris propriis*: on the list of Cardano's most popular works see 38, 83, 94. The *De fato* was written in 1533 in response to Pomponazzi and others, but destroyed unpublished in 1570. See Maclean, *Girolamo Cardano, De libris propriis*, 53. The *De arcanis aeternitatis* was first written in 1544, and subsequently reworked. It first appeared in print in Cardano's *Opera omnia* of 1663 (Maclean, *De libris propriis*, 68–70). The *De rerum varietate* was first published in Basle in 1557, pirated at Avignon in 1558, and published in German translation at Basle in 1559 (94). On this work, see also David F. Larder, "The Editions of Cardanus' *De rerum varietate*," *Isis* 59 (1968): 74–77. *De subtilitate* was published in Nuremberg in 1550. Its publishing history is discussed below. It was also published in a French translation: *Les livres de Hierome Cardanus . . . intitules De la subtilité, & subtiles inventions, ensemble les causes occultes, & raisons d'icelles, traduis de latin en françois, par Richard Le Blanc* (Paris, 1556).

[7] Alfonso Ingegno, "The New Philosophy of Nature," in *The Cambridge History of Renaissance Philosophy*, ed. C. B. Schmitt and Q. Skinner (Cambridge: Cambridge University Press, 1988), 236–63, here 247.

[8] Jean Fernel, *De naturali parte medicinae libri septem* (Paris, 1542). Later known simply as the *Physiologia*, on its role as the first single-volume compendium of Galenism see John Henry and John M. Forrester, "Tradition and Reform: Jean Fernel's *Physiologia* (1567)," in Jean Fernel, *Physiologia (1567)*, trans. and annot. J. M. Forrester, *Transactions of the American Philosophical Society* 93 (2003): 1–12. For details of the publishing history of this work, see Sir Charles Sherrington, *The Endeavour of Jean Fernel, with a List of the Editions of his Writings* (Cambridge: Cambridge University Press, 1946).

and the rediscovery of ancient alternatives to the philosophy of Aristotle were already making it apparent that the prevailing Aristotelian natural philosophy was in dire need of reform. But if Cardano refused to endorse Aristotelianism completely, he did not go so far as to offer a fully worked-out alternative system. Such alternative systems, beginning from initial principles which were radically different from Aristotle's, began to appear later with the *De rerum natura iuxta propria principia* (1586) of Bernardino Telesio (1509–1588), the *Nova de universis philosophia* (1591) of Francesco Patrizi (1529–1597), and subsequent works by numerous other thinkers—culminating in the *Principia philosophiae* (1644) of René Descartes (1596–1650).[9]

In the *De subtilitate*, as Nancy Siraisi has suggested, "Aristotelian natural philosophy is subverted, but not discarded."[10] Like other would-be reformers of natural philosophy among his contemporaries (Paracelsus, Girolamo Fracastoro, and Jean Fernel), Cardano's natural philosophy remains fundamentally Aristotelian, but it incorporates a varied, and sometimes bewildering, range of individual refinements of Aristotelianism, or specific deviations from it. Accordingly, Cardano could hardly be described as a systematic thinker. Although the *De subtilitate* begins clearly enough, with a discussion of what Cardano takes to be the first principles of all things, matter, form, spirit, place, and movement, the bulk of the work can be seen as a miscellany of phenomena which Cardano sees as exposing the inability of Aristotle's neat system to account for all things.

Aristotle had sought to reduce all natural phenomena to a restricted number of categories, and to explain them in terms of a highly reductionist scheme. Cardano's *De subtilitate*, if not explicitly anti-reductionist, gives the reader the impression that to understand the natural world one must first be fully aware of its dizzyingly diverse variety. As Anthony Grafton has suggested, "*On subtlety*, accordingly, resembled at times a verbal equivalent of Aldrovandi's museum . . . Cardano composed an artificial world of wonders."[11] Although Cardano saw himself as presenting an encyclopaedic and comprehensive work, for more systematic (and more strictly Aristotelian) critics like Julius Caesar Scaliger (1484–1558) and Rudolf Göckel, or Goclenius (1547–1628), the *De subtilitate* was, as

[9] Bernardino Telesio, *De rerum natura iuxta propria principia libri IX* (Naples, 1586); Francesco Patrizi, *Nova de universis philosophia* (Ferrara, 1591); René Descartes, *Principia philosophiae* (Paris, 1644).

[10] Siraisi, *The Clock and the Mirror*, 56.

[11] Grafton, *Cardano's Cosmos*, 163. See also Ingegno, "The New Philosophy of Nature," 249, and idem, *Saggio sulla filosofia di Cardano*. See, for example, Ulisse Aldrovandi, *Musæum metallicum in libros iiii* (Bologna, 1648), although Grafton is probably referring more loosely to all of Aldrovandi's extensive writings in ornithology, entomology, botany, and other aspects of natural history.

Ian Maclean summarises, "little more than a declamation, a hotchpotch of disparate and uncoordinated facts, explanations, and erroneous beliefs."[12]

In so far as the *De subtilitate* was intended to offer a comprehensive account of natural philosophy, complete in one volume, it may well be seen to mark "the beginning of a new phase in European culture." Although influenced by the innovations introduced into philosophy by Marsilio Ficino (1433–1499), Giovanni Pico della Mirandola (1463–1494), and Pietro Pomponazzi (1462–1525), and perhaps inspired by a scholastic compendium like the *Margarita philosophica*, Cardano was the first of the neoterics to make the whole of natural philosophy (and beyond) his province.[13] Although there are similarities with contemporary encyclopaedic works in natural history, and with contemporary encyclopaedic works in geography, most notably Sebastian Münster's *Cosmographiae universalis libri VI* (1550), Cardano's *De subtilitate*, for all its diffuseness, remains distinctively more philosophical in orientation than such other works, and can therefore be seen to have been more influential on succeeding generations of

[12] Ian Maclean, "The Interpretation of Natural Signs: Cardano's *De subtilitate* versus Scaliger's *Exercitationes*," in *Occult and Scientific Mentalities in the Renaissance*, ed. B. Vickers (Cambridge: Cambridge University Press, 1984), 231–52, here 237. On Scaliger see Vernon Hall, *The Life of Julius Caesar Scaliger, 1484–1558* (Philadelphia: American Philosophical Society, 1950). Göckel (Goclenius) was professor of philosophy and logic at Marburg, and with regard to his attitude to Cardano, a follower of Scaliger. See Rudolf Göckel, *Analyses in exercitationes aliquot* (Marburg, 1599). Similar views continued to be expressed much later. For Denis Diderot, for example, Cardano wrote "a multitude of writings, where their obscurity and digressions bring the reader to a halt at every step" (*Encyclopédie*, 3: 675–77). Even Morley, one of Cardano's nineteenth-century biographers, was dismissive of the *De subtilitate*: "It is impossible to stifle regret that Cardan's confused method and incoherent system should have rendered his work comparatively useless for the spread of true knowledge, and qualified it only for a place among the *labores ineptiarum*": Morley, *Life of Jerome Cardan*, 2: 106.

[13] On the links between Cardano's thought and these earlier thinkers, see Ingegno, "The New Philosophy of Nature," 236–50. Other precursors of Cardano with regard to reform of natural philosophy were Alessandro Achillini (1493–1512) and Agostino Nifo (1469/70–1538), but again, they did not attempt anything like a comprehensive natural philosophy. See Brian P. Copenhaver and Charles B. Schmitt, *Renaissance Philosophy* (Oxford: Oxford University Press, 1992), 327. Although Gregor Reisch's *Margarita philosophica* (Freiburg, 1503) predated *De subtilitate* it was entirely orthodox in its scholastic Aristotelianism. By adding the parenthetic comment "and beyond" we wish to make clear that Cardano's version of what was germane to natural philosophy was far wider than that accepted by contemporary scholastics. Generally speaking, mathematics and mechanics, the occult, and other things which Cardano glibly includes in his discussions would have been seen by more orthodox contemporaries as lying outside the discipline of natural philosophy.

reforming natural philosophers.[14] The potential usefulness to our understanding of a "hotchpotch of disparate and uncoordinated facts," while denied by Scaliger and Goclenius, was recognised, famously, by Francis Bacon (1561–1626), whose attempts to include comprehensive natural and artificial histories in his "Great instauration" of natural knowledge show distinct similarities to Cardano's *De subtilitate* and *De varietate.*[15]

As in the works of contemporary natural historians and geographers, experience plays a significant role in the *De subtilitate*, and Cardano's work must be recognised as one of the major conduits for introducing experientialism and empiricism into Renaissance and early modern natural philosophy. Cardano is explicit in affirming that experience is the only reliable authority, but more to the point, he frequently refers to his own experience, his personal familiarity, with the phenomena he describes throughout the *De subtilitate.* This frequent personal testimony keeps the author's personality ever before the reader's mind, and the *De subtilitate* shows some of the same concern to promote the author as the *De vita propria.* But the main aim, or at least the main effect, is to promote the importance of personal experience in the establishment of knowledge. Whether describing a weapon ("I have also seen one made of two pieces"), or an effective cure ("Personally, I know that pigeon dung and pellitory . . . extracted into water, can break up the hardest bladder stones"), or the way many stars in the Milky Way can appear as one milky light ("a feature even I have seen happen to be beautifully imitated by many candles"), or any number of other personal experiences ("While I was writing this, I noticed that wheat sown beside a hedge in a field had become stunted, dry and scanty"), Cardano declares in the closing sentences of the book that "What is set down here by way of examples is inserted . . . to enlarge experience."[16]

This is not to say, however, that Cardano presents a fully-fledged empiricism, much less an experimental method, in this unique work. Scientists today, after all, are still prone to interpret their experiments in terms of what they know, or think

[14] On developments in natural history in the Renaissance see N. Jardine, J. A. Secord, and E. C. Spary, eds., *Cultures of Natural History* (Cambridge: Cambridge University Press, 1996); William B. Ashworth, Jr., "Natural History and the Emblematic World View," in *Reappraisals of the Scientific Revolution*, ed. D. C. Lindberg and R. S. Westman (Cambridge: Cambridge University Press, 1980), 303–32. On developments in geography, and the work of Münster in particular, see Matthew McLean, *The* Cosmographia *of Sebastian Münster* (Aldershot: Ashgate, 2007).

[15] On Bacon see Stephen Gaukroger, *Francis Bacon and the Transformation of Early-modern Philosophy* (Cambridge: Cambridge University Press, 2001). On similarities between Bacon's enterprise and Cardano's see Ingegno, "The New Philosophy of Nature," 261–62; and Maclean, ed., *Girolamo Cardano, De libris propriis*, 27.

[16] We refer throughout this Introduction to page numbers of the 1560 edition of *De subtilitate.* These are indicated in this edition in the form: &106. The quoted passages are to be found at Bk II, 106; Bk II, 132; Bk IV, 268; Bk VIII, 515; Bk XXI, 1263.

they know, and have to guard carefully against letting accepted theory determine the significance of an experimental trial.[17] If empiricism remains fraught with epistemological pitfalls nearly four hundred years after Francis Bacon, Cardano is hardly to be blamed for allowing, on the supposedly reliable testimony of experience, many things that we would no longer hold tenable. Because our own lights lead us to suppose that some of the details in *De subtilitate* cannot be true, we are forced to suppose that Cardano was mistaken, or deceived, as a result of what can broadly be assumed to be wishful thinking—although it ought to be allowed that our own wishful thinking may be clouding the real issue.

The source of Cardano's experientialism can be found not just in the medical tradition to which he was a prominent contributor, and not just in the increased ambition among Renaissance neoterics to reject ancient authority and to discover the truth for oneself (ambitions that, as we have already noted, were prominent in contemporary natural history and geography), but also in the recently revived occult tradition.[18] Cardano is generally seen as a writer in the occult tradition, and the *De subtilitate* is one of the main reasons for this perception. As Maclean has pointed out, "its very title suggests strongly an occult subject and approach."[19] Moreover, having entitled the first book "The principles, matter, form, the vacuum, the resistance of bodies, natural motion, and position," he refers to it at the opening of Book V as being concerned with "the more occult principles, matter, form, the vacuum, the union of bodies."[20] Indeed, his first discussion of what he means by *subtilitas* suggests that his focus is on the arcane: *Subtilitas* is "the feature [*ratio*] by which things that can be sensed are grasped with difficulty by the senses, and things that can be understood are grasped with difficulty by the intellect."[21] The publisher of the first edition, Johannes Petreius, gave it an occult sheen by informing potential readers that the book discussed the causes, powers, and properties of more than fifteen hundred varied, uncommon, difficult, hidden, and beautiful things, all of them observed by the author in various places, by personal trials.[22]

Four years later, when the revised edition was published (1554), the vaunted fifteen hundred had become twenty-two hundred. Similarly, the *De subtilitate*'s

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[17] For a brief history of thinking about scientific method see John Losee, *Historical Introduction to the Philosophy of Science*, 4th ed. (Oxford: Oxford University Press, 2001).

[18] For a bibliographical survey of secondary sources on the historical development of empiricism see John Henry, *The Scientific Revolution and the Origins of Modern Science*, 3rd ed. (Basingstoke and New York: Palgrave Macmillan), especially Chaps. 2–4 (12–68).

[19] Maclean "The Interpretation of Natural Signs," 234.

[20] Cardano, *De subtilitate*, Book V, 335 (1560).

[21] Cardano, *De subtilitate*, Book I, 1 (1560). Maclean, "The Interpretation of Natural Signs," 238. There is a fuller discussion of what Cardano means by *subtilitas* below.

[22] This appears on the title page of the Nuremberg, 1550 edition, and the reverse title page of the Paris, 1551 edition. Quoted from Grafton, *Cardano's Cosmos*, 163.

greatest critic, J. C. Scaliger, also contributed to its reputation as an occult work by declaring his own critique to be exoteric, thereby implying the esotericism of his target.[23]

It is important to note, however, that Cardano deliberately rejected just this aspect of the magical tradition which Scaliger implicitly imputes to him. It was a standard assumption among those in the occult tradition that some knowledge was worthy only for adepts and was therefore kept esoteric. The clear implication of this seemed to be that what was exoteric, and available to all, was either trivial or debased and distorted to protect the real esoteric truths. Cardano's *De subtilitate* was one of the first books to break this mould, offering to make previously esoteric knowledge available to all. It seems clear that Cardano was perfectly ingenuous about this intention. His aim, after all, was not to establish his own reputation as a magus, but to reform Aristotelian natural philosophy, and he could do so only by showing the relevance of the erstwhile esoteric matters he discussed to a proper understanding of the natural world.[24] Having said that, however, much of the discussion in *De subtilitate*, as noted above, remains recalcitrantly obscure. This is no doubt due to a combination of Cardano's lack of clarity and the inherent unfamiliarity of many of the issues he discusses. Certainly there was plenty in the subject matter of the *De subtilitate* which would have been more typically found in a work of magic, rather than a work of natural philosophy, including discussions of sympathy and antipathy, talismans, marvellous cures for disease and other natural marvels, the activities of demons, and the prominent role of *spiritus*, which Grafton has described flamboyantly as "the super-glue of the Renaissance magician's cosmos."[25]

The attempt to use the formerly secretive magicians' cosmos in explicating a reformed, post-Aristotelian natural philosophy may help us to understand why the *De subtilitate* was so influential. If the book was perceived as making accessible what had previously been confined to wise and virtuous adepts, it would surely attract a wide audience among the curious. Certainly, Cardano tells us that this most influential of his books was more popular among the "multitude" than it was among the learned.[26] It is not clear just who he means by the "multitude,"

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[23] Julius Caesar Scaliger, *Exotericarum exercitationum liber quintus decimus, De subtilitate* (Paris, 1557). The French critic Charles Nisard (*Les gladiateurs de la république des lettres* [Paris: Lévy, 1860], 370) wryly observed that Scaliger's object seemed to be to deny all that Cardano affirmed and to affirm all that Cardano denied ("il parut s'appliquer à nier ce que Cardan affirme et à affirmer ce que l'autre nie").

[24] Maclean makes a similar point: Maclean, "The Interpretation of Natural Signs," 235–37.

[25] Grafton, *Cardano's Cosmos*, 162. Further confirmation of Cardano's worthiness to be included in the occult tradition can be found throughout Siraisi, *The Clock and the Mirror.*

[26] Maclean , ed., *Girolamo Cardano, De libris propriis*, 39.

but it seems reasonable to assume that the work had a wide circulation. Perhaps Cardano meant that his book was appreciated by those who, in the disciplinary hierarchies of the day, were below the status of natural philosophers and theologians; those such as mathematical practitioners, alchemists, elite craftsmen, and others who made a living from trying to understand, and exploit, natural phenomena.[27] Be that as it may, there can be no denying that the *De subtilitate* was widely read by the learned too, and continued to be taken seriously well into the seventeenth century.[28]

Another striking and unique aspect of the *De subtilitate*, and one which has not so far been noted by scholars, is the way discussions of machines stand side by side with discussions of natural processes, and even more remarkable, the way mathematical calculations and demonstrations sit alongside natural philosophical discussions.[29] Much recent—and important—work in the history of science has show how the fairly strict disciplinary separation of natural philosophy from mathematics gradually began to break down from the sixteenth century through to the triumphant appearance of Isaac Newton's demonstration of the *Mathematical Principles of Natural Philosophy* (1687). For most contemporaries of Cardano, Newton's title would have been bafflingly inappropriate for any serious work. Natural philosophy was concerned with providing explanations of how natural physical processes and events took place. The explanations, if they were to count as properly philosophical, had to be couched in terms of causes. Mathematics, by contrast, could not offer explanations but only a particular kind of technical description of a physical system. Causes had no place in mathematical presentations, and so mathematics was generally held to be incompetent with regard to natural philosophy.

The Scientific Revolution of the late sixteenth and seventeenth centuries used to be seen, at least in large measure, in terms of the "mathematization of the world picture," which took place as natural philosophers became aware of the importance of mathematics for understanding the natural world. Recent work has shown that the mathematical practitioners themselves played a bigger role than used to be acknowledged, but crucially important, however, were those thinkers

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[27] Consider, for example, the personnel discussed in William Eamon, *Science and the Secrets of Nature* (Princeton: Princeton University Press, 1994); Pamela H. Smith, *The Body of the Artisan* (Chicago: University of Chicago Press, 2004); and Mario Biagioli, "The Social Status of Italian Mathematicians, 1450–1600," *History of Science* 27 (1989): 41–95.

[28] For indications of the readership of *De subtilitate* see Eckman, *Jerome Cardan*, especially Section IV (59–89); Jensen, "Cardano and his Readers in the Sixteenth Century;" and below.

[29] But see Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 128–43.

who contrived to be both mathematicians and natural philosophers.[30] The big names here are Galileo (1564–1642), Descartes (1596–1650), and of course Isaac Newton (1642–1727), but it is at least arguable that Cardano should be acknowledged as one of the very first of such hybrid thinkers.

From our perspective it might seem perfectly natural that a consummate mathematician, as Cardano certainly was, should use his mathematics while trying to expound physical phenomena. But this would certainly be an anachronistic view. Given the intellectual separation of natural philosophy and mathematics before the modern period, it is entirely remarkable that Cardano so glibly turns to mathematics in the *De subtilitate*, and then turns back again to natural philosophizing. The same might once have been said about his readiness to discuss the operation of machines and other technological devices in the context of natural philosophy. Following the influential work of Fritz Krafft, scholars have accepted his suggestion that the study of mechanics was regarded by pre-modern thinkers as the study of an artificially constrained nature, and therefore the study of effects which were "contrary to nature." Accordingly, for pre-modern thinkers, mechanics and the study of technology could reveal nothing about the natural world and natural processes.[31]

However, recent research has shown that technology was not regarded by Aristotle, the pseudo-Aristotelian author of the influential *Mechanical Problems*, and other ancient writers as inevitably contrary to nature, but rather as going beyond what nature could achieve unaided.[32] According to Aristotle, art can go beyond nature, but only by enabling what nature would have achieved if it could have pursued its normal course further than it habitually does.[33] Far from being contrary to nature, the operation of machinery was seen as amplifying natural processes. The mechanical arts, therefore, could clarify natural processes and natural phenomena, helping us to understand them more fully.

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[30] Literature in this area is growing apace. See, for example, Robert S. Westman, "The Astronomer's Role in the Sixteenth Century: A Preliminary Survey," *History of Science* 18 (1980): 105–47; Jim Bennett, "The Mechanics' Philosophy and the Mechanical Philosophy," *History of Science* 24 (1986): 1–28; Nicholas Jardine, "Epistemology of the Sciences," in *Cambridge History of Renaissance Philosophy*, ed. Schmitt and Skinner, 685–711; Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago: University of Chicago Press, 1995).

[31] Fritz Krafft, "Die Anfänge einer theoretischen Mechanik," in *Beiträge zur Methodik der Wissenschaftsgeshichte*, ed. W. Baron (Wiesbaden: Steiner, 1967), 12–33; and idem, *Dynamische und statische Betrachtungsweise in der antiken Mechanik* (Wiesbaden: Steiner, 1970).

[32] Mark J. Schiefsky, "Art and Nature in Ancient Mechanics," in *The Artificial and the Natural*, ed. B. Bensaude-Vincent and W. R. Newman (Cambridge, MA: MIT Press, 2007), 67–108.

[33] Schiefsky, "Art and Nature in Ancient Mechanics," 74.

Even so, the discussion of mechanical marvels was not common in scholastic natural philosophy, and Cardano's readiness to discuss the workings of machines or technological processes in the middle of an account of one natural phenomenon or another shows a dramatic contrast with other contemporary works of natural philosophy. Again, recent scholarship in the history of science has shown how mechanics, once nothing more than a body of craft know-how, came to be introduced first of all into mathematics, and subsequently into natural philosophy, culminating in the Cartesian claim that all physics was merely mechanics.[34] Cardano's role in this story has so far barely been noticed by scholars,[35] but given the success of the *De subtilitate*, and the way Cardano almost routinely slips into discussing machines and the mathematics of how they work to illustrate a point in natural philosophy, it seems hardly credible that it should not have played some role in this story.

The relations between "science" and "religion" provide another prominent area of modern scholarly interest, but again Cardano and the *De subtilitate* have tended to be overlooked in this scholarship.[36] It is well known, of course, that Cardano was arrested by the Inquisition and imprisoned briefly in 1570. But uncertainty remains as to the precise reasons for his arrest.[37] Speculation has

[34] See, for example, Bennett, "The Mechanics' Philosophy and the Mechanical Philosophy"; idem, "The Challenge of Practical Mathematics," in *Science, Culture and Popular Belief in Renaissance Europe*, ed. S. Pumfrey et al. (Manchester: Manchester University Press, 1991), 176–90; W. R. Laird, "Patronage of Mechanics and Theories of Impact in Sixteenth-century Italy," in *Patronage and Institutions*, ed. B. T. Moran (Woodbridge: Boydell Press, 1991), 51–66; Alan Gabbey, "Newton's *Mathematical principles of natural philosophy:* A Treatise of Mechanics?" in *The Investigation of Difficult Things*, ed. P. Harman and A. Shapiro (Cambridge: Cambridge University Press, 1992), 305–22; idem, "Between *ars* and *philosophia naturalis:* Reflections on the Historiography of Early Modern Mechanics," in *Renaissance and Revolution*, ed. J. V. Field and F. A. J. L. James (Cambridge: Cambridge University Press, 1993), 133–45.

[35] The notable exception is Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 128–43.

[36] Strictly, use of the word "science" here is anachronistic, but it is used as shorthand for natural philosophy and other aspects of natural knowledge. Similarly, even the use of the blanket term "religion" might be misleading. Our aim here is simply to draw attention to Cardano's relevance to the historiography of what is routinely referred to as "the relations between science and religion." But see, for example, John Brooke, *Science and Religion: Some Historical Perspectives* (Cambridge: Cambridge University Press, 1991); and Peter Harrison, *"Religion" and the Religions in the English Enlightenment* (Cambridge: Cambridge University Press, 1990).

[37] The fullest account is provided in Jerzy Ochman, "Le procès de Cardan," *Tijdschrift voor de Studie van de Verlichting Bruxelles* 7 (1979): 125–59; but see also Ian Maclean, "Girolamo Cardano: The Last Years of a Polymath," *Renaissance Studies* 21 (2007): 587–607.

tended to alight on the horoscope which Cardano drew up for Jesus Christ, but this in itself would not necessarily have caused undue consternation. It was common among astrologers to insist, for religious reasons, that the stars do not compel but only impel (*stellae agunt non cogunt*), and a horoscope relating to events so long past would have been understood as being offered as a supposed demonstration of how the stars might reveal one's fortunes. Such a horoscope might well have been seized upon by Cardano's enemies to try to get him into trouble, but their stratagem could not have succeeded automatically.[38]

There are, however, a number of other aspects of Cardano's writings which might have attracted the attentions of inquisitors. A number of elements in his writings might have been construed as unduly sceptical, perhaps even atheistic (although these might simply have been nothing more sinister than critiques of Aristotle); while other features might have been construed as heretical.[39] The problem with these imputations is that one of the most seemingly heretical aspects of Cardano's "cosmos" is his attitude to demons, but such a belief tells against him being sceptical, much less atheistic. Indeed, Cardano himself is supposed to have insisted that belief in demons, miracles, and the immortality of the soul stand or fall together.[40]

On the face of it, there are also a number of aspects of Cardano which suggest a man who at the very least was willing to conform to the doctrines of his Church. At the end of his discussion of "Guardian Angels" in his autobiography, he defers to the Church: "in points wherein I can fall into error, I betake myself to my intellectual betters, that is, to the theologians."[41] Similarly, he ends the present work with an effusive version of the standard Catholic deferral to what is set down by Holy Mother Church:

> So Thou, most high God, from whom all good proceeds, whose nod moves everything, whose power is confined by no limits, infinite brightness, who alone providest true illumination, alone art truly eternal, complete in Thyself, known only to Thyself, whose wisdom exceeds all thought, single and without compeer, outside whom there is nothing, who hast directed me like an earthworm in the shade of knowledge, to whom I owe anything written here that is true—the mistakes are the outcome of my ambition, rashness and haste—do Thou pardon me; and by illuminating my mind in accord with Thy tireless generosity, turn it to better things.[42]

[38] For a discussion of Cardano's horoscope of the Christ see Grafton, *Cardano's Cosmos*, 151–55; and Ernst, "Veritatis amor dulcissimus."

[39] For a fuller discussion, see Eckman, *Jerome Cardan*, 33–37.

[40] At least, so claims Lynn Thorndike, *History of Magic*, 5: 567. He gives no specific reference for this, although it appears while he is discussing the contents of *De rerum varietate*.

[41] Cardan, *The Book of my Life*, 247.

[42] Cardano, *De subtilitate*, Bk XXI, 1264 (1560).

Furthermore, Cardano always remained true to his Catholicism, even turning down a lucrative medical appointment at the Danish royal court, not only because of the severe climate in Denmark, but also because the Danes were "given to another way of worship."[43]

Historians of atheism may still suggest, however, that formulaic responses in printed works do not signify sincere belief, and that Cardano's real attitudes are more likely to be displayed in the thick of philosophical discussion. Accordingly, some attention has been paid to Book XI of the *De subtilitate*, "On the Necessity and Form of Man," which, according to G. E. Lessing, had been noticed by earlier commentators as "locum impium et scandalosissimum, locum offensionis plenissimum."[44] As far as we can see, however, the only contentious part of this is the Epicurean account of the chance formation of different kinds of animals, and the subsequent elimination of those forms unsuited for survival. But it seems perfectly clear that Cardano does not accept the Epicurean account as plausible. After all, he points out, there are plenty of animal forms which could be viable but which do not exist, such as "wolves with horns, and dogs with sharp claws."[45] If this passage was used to charge Cardano with impiety, it would seem to have been the work of his enemies, rather than based on a fair reading.

It may well be, therefore, that the judgement of James Eckman, echoing that of Giovanni Vidari, is correct, and that Cardano's brief skirmish with the Inquisition was not so much the result of having written irreligious works, but simply "because he happened to live in an age in which any deviation from an authority that had just sustained a multitude of powerful assaults was certain to be investigated exhaustively."[46] Equally, it may be the case that the current state of scholarship on Cardano does not allow us to reach a secure conclusion. Given the importance of the *De subtilitate* and his other works, and his historical association with the other Italian Renaissance nature philosophers, Telesio, Patrizi, Bruno, and Campanella, all of whom suffered (though to differing extents) under the Inquisition, it seems hard to deny that the contemporary religious implications of Cardano's work deserve more scholarly examination.

Cardano's great work ought to play a major role also in ongoing efforts to provide histories of the development of books. Although the previous century had seen the first appearance of single-volume surveys of the whole of natural philosophy, these surveys usually provided only very brief outlines, and were, of

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43 Cardan, *The Book of my Life*, 16.

44 See Eckman, *Jerome Cardan*, 35. Eckman cites G. E. Lessing, "Rettung des Hier. Cardanus," in *Sämmtliche Schriften* (Berlin, 1838), 6: 44–68.

45 Cardano, *De subtilitate*, Bk XI, 792 (1560).

46 Eckman, *Jerome Cardan*, 36. Eckman is deferring to Giovanni Vidari, "Gerolamo Cardano," *Bollettino della Società Pavese d'istoria patria* 4 (1904): 568–94. He is also referring, of course, to the "multitude of powerful assaults" leveled against the Roman Church during the Protestant Reformation.

course, entirely in keeping with the neo-Aristotelianism that had been developed in the scholastic tradition. Even the longer and more comprehensive surveys which began to appear at the beginning of the sixteenth century, such as the *Margarita philosophica* of Gregor Reisch (c. 1467–1525) and the *Compendium naturalis philosophiae* of Frans Titelmans (1502–1537), were entirely scholastic.[47] Cardano's *De subtilitate* was the first attempt to offer a single-volume alternative to such works, offering a supposedly comprehensive (if not systematic) account of the natural world and all it contained from a perspective that was by no means slavishly Aristotelian in its primary precepts and assumptions.[48] As such, it can hardly have failed to attract contemporary attention.

If we are seeking for reasons as to why Cardano chose to write his comprehensive survey of natural philosophy when he did, developments in the writing and publishing of philosophical textbooks might not cover all the ground. Cardano himself, famously, told readers of the *De subtilitate* that he wrote it at the prompting of a series of dreams.

> In sleep, I have been urged more than once to write this book, and as it appeared to me, to write it divided into 21 parts; the themes were diverse, and around the middle, some scraps of geometry. Then throughout, diverse novel discussions, quite refined, and with true subjects; with more than ordinary lucidity of language, combined with some welcome obscurity; and then the continuity of the style and the subtlety of the reasoning made the project look virtually divine to me, so much so that in my sleep I was overwhelmed by so much pleasure that I have never felt its like. I seemed to be carried out of my senses, and after the sleep, even the recollection of this pleasure used to afford me marvellous delight. I could recognise the material, which would cover everything, and the book's name, a slim and beautiful mark. The book seemed printed at some distance, and with few copies in the town.

Continuing dreams led him to successively expand the work:

> So when this had often happened to me, I started the little book with four sheets of paper at the outset; later I increased it to seven, then to 35. And never in the meantime did those same images cease, nor that pleasure that I used to feel while reading in sleep; but the more rarely it came back into

[47] Reisch, *Margarita philosophica* (Freiburg, 1503); Frans Titelmans, *Compendium naturalis philosophiae* (Antwerp, 1530).

[48] On historical changes in books of natural philosophy see Charles B. Schmitt, "The Rise of the Philosophical Textbook," in *Cambridge History of Renaissance Philosophy*, ed. lic. idem and Skinner, 792–804. For more general works on the history of the book, see Elizabeth L. Eisenstein, *The Printing Press as an Agent of Change*, 2 vols. (Cambridge: Cambridge University Press, 1979); and Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making* (Chicago: University of Chicago Press, 1998).

> a dream, the more the book kept growing. It grew later to 57 sheets, and finally to 76, and then was published for the first time with a table added. But when it was visibly half the size of the one that was shown to me in my dream, I thought it was for completion by someone else elsewhere. For the same book had already been printed three times, at Nuremberg first, then at Lyon, and finally at Paris. But when I had happened on Galen's words in which the way to finish books is set out, I took up the thread again, and completed it to the standard of this way, adding nearly as much as there had been in the first edition, and was assisted by nearly the resources that I applied finally in the preceding book. The total increase amounts to fifty-six pages, and the whole book to 132. Then with the illustrations added, I reckon it differs little at all from the one I saw during repose. But I cannot increase it even if I want to, firstly because the sequence is complete, and then because it would be necessary to consider the whole thing from the start, which for me now would be not just inconvenient but impossible.[49]

Cardano was so impressed by this dream that he commemorated it by having an account of it, in his own words, "engraved on the back of our copper plates."[50] The dream ceased to present itself as soon as the book was first published, at Nuremberg, except for one reappearance of the dream during his trip to Scotland in 1552, the day before he examined a book whose reading gave him particular pleasure.[51] Cardano also mentions a remarkable dream in which he appeared to be in heaven after his death, and in which the books of his own work *De rerum varietate* were shown to him.[52]

It is worth noting that Cardano tells us that these dreams even provided him with the somewhat cryptic title of his work ("I could recognise the matter, which would cover everything, and the book's name"). As has often been pointed out, it is by no means clear what Cardano meant by *subtilitas*, and why he chose to characterise his survey of natural philosophy as a "detailed and extensive account of Subtlety."[53]

Consider first the meanings it covered in the Latin of classical antiquity, a language which Cardano inherited and which in his time was the *lingua franca* of

[49] Cardano, *De subtilitate*, Book XVIII, 1180–1182 (1560). He was able, however, as we have already noted (in text at note 5) to include material he had left out of *De subtilitate* in the various editions of *De varietate rerum*. For annotations to these long passages consult the edited text below.

[50] *De subtilitate*, Book XVIII, 1182 (1560): "à tergo aerearum nostrarum imaginum insculpi feci." It is not entirely clear what these copper plates were.

[51] Cardano, *De libris propriis* (1562), in Maclean , ed., *Girolamo Cardano, De libris propriis*, 263. On Cardano's trip to Scotland see C. L. Dana, "The Story of a Great Consultation: Jerome Cardan Goes to Edinburgh," *Annals of Medical History* 3 (1921): 122–35.

[52] *De subtilitate*, Book XVIII, 1183 (1560).

[53] Cardano, *De subtilitate*, Book 21, 1263 (1560).

European serious discourse. He possessed a wide acquaintance with its literature, commending to his own sons a list comprising (to name the Latin authors only) Vergil, Horace, Priscian (the Latin grammarian), Cicero, Quintilian, Sallust, Suetonius, Vitruvius, and Pliny.[54] Not, of course, that authors of his own time considered themselves rigidly bound by the usage of the past; they had new topics to cover that were previously unknown, some of which entailed the adoption of wholly new words from Arabic or other languages. But the Latin dictionaries of his time drew heavily on the authoritative classics, and little on subsequent writings.[55]

For the authors of classical antiquity, *subtilitas* covered, firstly, items in the natural or manufactured world which possessed fineness of texture or consistency, slenderness, and then fineness of detail, delicate workmanship, neatness. This extended to the precision or logical quality of an argument or a speech. Secondly, it covered characteristics of people examining or making such items: fineness of perception, acuteness, refinement of taste or judgment, attentiveness to finer points, thoroughness, subtlety, minuteness.[56]

It is by no means immediately obvious which of these two meanings Cardano had in mind. His "subtilitatis diffinitio" in the opening words of Book I of *De subtilitate* announces that "The aim of our undertaking in this work is to discuss subtlety. It is the feature [*ratio*] by which things that can be sensed are grasped with difficulty by the senses, and things that can be understood are grasped with difficulty by the intellect." This is not as helpful as it might be. It looks here as though Cardano intends the second meaning of subtlety: a feature of the human mind which struggles to grasp, or even notice, the finer points of things. Certainly, Scaliger seems to have assumed that Cardano thought of *subtilitas* as a *vis intellectus*, a power of the mind.[57]

At the start of his long and abrasive review of *De subtilitate*,[58] Scaliger debated the meaning of the word *subtilitas*, with special emphasis on its use by classical authors such as Cicero and Lysias. He began from the fineness of weave in textiles or the like, and framed a definition covering at least one aspect of it, as "vis intellectus, qua difficilia cognitu facilè comprehenduntur" ("an intellectual power through which items hard to appreciate are easily grasped"). Thus for him *subtilitas* holds its second meaning: a quality you have, not a quality of

[54] Cardano, *De praeceptis ad filios*, cap. 18 (*Opera omnia*, 1: 479).

[55] For instance, the *Dictionarium latinogallicum* of Robert Étienne (1544).

[56] Elio Nenci employs the descendant Italian word "sottigliezza." See Girolamo Cardano, *De Subtilitate, Edizione critica (Tomo I, Libri I–VIII)*, ed. Elio Nenci (Rome: Franco Angeli, 2004), 17.

[57] Scaliger, *Exercitationes* (above, n. 23), fol. 2r. We draw here on the excellent discussion on the meaning of subtlety for Cardano in Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 28–38.

[58] Scaliger, *Exercitationes*, 1(1), fols. 1–4.

outside objects; it is in the mind which perceives nature. It has been claimed that for Scaliger "subtlety is sited not in nature but in the human mind, a distinction between nature and man's perception of nature that looks forward to the division of primary from secondary qualities so crucial to the new sciences, as developed by Galileo, Descartes, and Locke."[59] But if there was a foreshadowing of the primary/secondary distinction here, it can be seen in Cardano as much as in Scaliger. For there can be no doubt that Cardano was also aware that the notion of *subtilitas* could be seen as an internal psychological phenomenon.

It is evident when Cardano expands on subtlety in Book XVII, for example, that he means it as a feature of the human mind. He writes there of the commendable skill of the surgeon operating for cataract or the stone,[60] or of the physician discriminating arterial pulses of diverse character, or the student of language discriminating and appreciating the sounds of words, or the leader making shrewd judgments. In Book XVI he even mentions twelve thinkers who have distinguished themselves by their subtlety, including Archimedes, Aristotle, Apollonius, Euclid, Geber, Galen, and even John Duns Scotus. Undeniably, as Nancy Siraisi has pointed out, Cardano "sometimes wrote as if subtlety itself were a quality of mind possessed by specially gifted persons, surely including himself."[61]

Elsewhere, however, Cardano uses both meanings of "subtlety" side by side: the effort to grasp the *subtilitas* in things leads to increased *subtilitas* in the person who so strives. As Pierre Magnard has suggested, there is an obvious progression: from the detail in a fabric that the eye finds hard to discriminate to the complexity in what the intellect discerns.[62] We might think of this in a culinary context: to appreciate lobster meat requires a subtle palate—so lobster meat is subtle, as is the gourmet's palate.

Throughout the bulk of *De subtilitate*, Cardano more often than not seems to regard "subtlety" as a characteristic of things. Subtlety is not just a mental acuity, therefore, but a real feature of the material world. To give just one example, Cardano remarks at one point that "Chemists can therefore alter colour and weight, but not subtlety and robustness. Since testing for subtlety would be laborious and ambiguous, they chose to test gold by fire, and this is the reliable evidence on this issue."[63] In the light of Cardano's dominant approach to the issue, Ingo Schütze

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[59] Vickers, ed., *Occult and Scientific Mentalities in the Renaissance*, "Introduction," 12. Vickers, it should be noted, is seeking here to champion those, like Scaliger, whom he regards as representatives of the "scientific mentality," and to denigrate those who represent the "occult mentality." He sees Cardano as belonging to the latter category.

[60] *De subtilitate*, Book XVII, 1103 (1560).

[61] *De subtilitate*, Book XVI, 1010–1012 (1560). Siraisi, *The Clock and the Mirror*, 7.

[62] See Pierre Magnard, "La notion de subtilité chez Jérôme Cardan," in *Girolamo Cardano*, ed. Baldi and Canziani, 159–67.

[63] *De subtilitate*, Book VI, 421 (1560).

is surely right to say that the problem of why things appear subtle to our intellects is *not* the theme of *De subtilitate.*[64]

There are similar usages of "subtilis" and "subtilitas" in two passages of his major mathematical work, *Ars magna.*[65] In the first,[66] he devises a cunning ("subtilis") scheme to find a pair of numbers with a specified product and meeting other conditions (such as the sum of their cubes). "Subtilis" here is a characteristic of the scheme. In the second,[67] he addresses the issue of the square root of a negative number. It is "subtilis," and he says he had to torture himself to accept it. The concept of complex numbers, which later came to be written in the form $a + b\sqrt{-1}$, and thus to include the square root of the negative number minus one, was not yet recognised. The complexity of such mathematical concepts, their subtlety, is a feature of the realm of mathematics, not simply a feature of how the mind deals with abstract concepts.

Things are less clear, however, when Cardano discusses the features of subtlety in the field of oratory. It is impossible to tell whether he sees these subtleties as built into the nature of language, or merely as aspects of the mind of the speaker.

> There are seven ways of subtlety in oratory, [he writes,] and among them single ones that make it more obscure. The first way in the grouping is the grammatical: metuo, me tuo, me tu o. The second is the sophistical, for instance, I am telling a lie. The third is mathematical, and is threefold: either combined, for instance, which point in a circle is closer to the circumference; or from the assumptions, as whether the assumptions in the proof by Archimedes by helices make things plain about the straight line equal to the circumference of a circle; or from what has been proved, as whether a general rule for a cube equal to things and to a number can exist. The fourth is physical, and is double: from the thing, and from the cause. From the thing: whether new species of things are provided in individual seasons. From the cause, whether the movement of heaven follows eccentric circles. The fifth consists in the uninterrupted continuity of speech, as in the little book on the *Immortality of the Soul*, when we gradually draw a person along from one thing to another. The sixth is from the passage from kind to kind, as when we explain drawing up water with a screw, because while the empty lower part rotates, it is filled up. The seventh is from law: the man who has not secured half the votes is not to be freed, the man who has not obtained two shares of the votes is not to be condemned. But since the cases of many of the rest would stay undecided, by another law they are judged as freed or condemned according as each of them was closer to

[64] Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 29.

[65] See Maclean, *Girolamo Cardano, De libris propriis*, 80 (item M69).

[66] Cardano, *Ars magna*, Chap. XXXV, Rule 2 (1993 edition [211]).

[67] Cardano, *Ars magna*, Chap. XXXVII, Rule 2, Demonstration (1993 edition [219–20]). We are indebted to Dr Jackie Stedall for advice here.

> the number of votes. There are twelve judges: someone is condemned by seven and acquitted by five. If eight had condemned him, he would be punished; if six had acquitted him, he would be freed—with five acquitting, and seven condemning, he is geometrically condemned, but freed in accord with a special prerogative, which favours the acquitters; arithmetically his case will be undecided. There are many other modes of this kind, which for the sake of brevity I intend to pass by, since they can be worked out from what precedes.[68]

It is difficult to unite these seven under the rubric of oratory, let alone decide what they tell us about the nature of subtlety. The fact remains, therefore, that it is difficult to fathom what Cardano means by *subtilitas.* Neverthless, the encyclopaedic nature of the *De subtilitate* itself confirms that Cardano thought of it as a feature of the physical world and its varied contents. Subtlety is not just a feature of some aspects of the world, Cardano evidently believes, but of every aspect, and so a complete treatment of the way subtlety manifests itself in things must range over all things. A sense of this is provided in Book II, when Cardano makes some general observations about the subtlety of things:

> Some then, such as air, are described as rarefied in themselves; some rarefied in quantity, like hairs; some so because they flow, like blood; some so because they can be divided into very tiny parts, like gold; others because they have several of these characteristics, like spirits, which are the instruments of our operations.

It is this same belief that subtlety manifests itself in all things which accounts for Cardano's refusal to recognise the traditional distinction between the natural and the artificial:

> And most things are made fine-grained by technical skill, like lead, which is so much refined by technical skill that it is reduced to the powder from which clocks are usually made; when molten it is rapidly rotated in a mortar, to convert it to powder when it cannot be held together. Though technical skill reduces timber or stone or metal to very fine particles, it still does not mix or break down the substance, but only the quantity.[69]

Needless to say, Scaliger objected to the universality of Cardano's concept of *subtilitas*, seeing it as fundamentally incoherent because it was applied indiscriminately

[68] On this see Cardano, *Ars magna*, chapter XI, and the editor's n. 11 in the Preface to the 1993 edition [xvi], which notes how Cardano refers to their "sophisticated" nature.

[69] *De subtilitate*, Book XVII, 1106–1107 (1560). Small wonder that Anthony Grafton remarks that "often *On Subtlety* seems designed as much to mystify as to explain." See Grafton, *Cardano's Cosmos*, 164.

to substances, accidents, and representations.[70] It is evident, however, that Cardano was not thinking within the limits set by Aristotelian categories, and gave no thought to such niceties. Small wonder, therefore, that contemporaries who could not so easily shake off their Aristotelian heritage saw the *De subtilitate* merely as "a hotchpotch of disparate and uncoordinated facts, explanations, and erroneous beliefs." Rambling and diverse though all this might have seemed to his contemporaries, we may nonetheless hesitantly surmise that Cardano saw a shared feature in the problems to which he set his mind, a feature shared with the mind itself. As Ian Maclean has suggested, "All subtlety lies at the very edge of perceptibility and intelligibility; thus a series of related concepts is attracted to it—difficulty, rarity, thinness, implausibility, and unexpectedness . . . Cardano insists that it is identified by a true method and supported by evidence drawn from experience."[71] It is hard to resist the conclusion, therefore, that Cardano simply wanted to impress upon a readership used to the straitjacket of Aristotelianism that "There are more things under heaven and earth . . . Than are dreamt of in your philosophy."[72]

Notwithstanding its difficulties, the work was immediately successful, being reprinted many times from its first appearance.[73] As Maclean has pointed out, "France in particular seems to have been receptive to his ideas; the *De subtilitate* appeared in French in 1556, translated by the professional translator Richard LeBlanc; his rendering was reprinted in 1566, 1578 and 1584."[74] We have already noted that Cardano regarded *De subtilitate* as one of his most widely read works in his own lifetime, and it retained such a place in Cardano's own assessment that he included it in a list of his books that according to his will, he especially wished republished after his death.[75] When the expanded edition of *De subtilitate* appeared in 1560, Cardano was near the zenith of his career, having

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[70] *De subtilitate*, Book II, 123–124 (1560). Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 33–34, makes the important point that Cardano's concept of subtlety in nature differs greatly from the Aristotelian view. Aristotle's term is λεπτότης (e.g. in *Physics* 215b28), and is discussed by the late antique commentators. The same word is used by Aristophanes to mean "subtlety of wit."

[71] Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 37, n. 115. For Scaliger, subtlety (as a mental phenomenon) could only be an accidental property.

[72] Maclean, "Interpretation of Natural Signs," 238.

[73] On the various editions of *De subtilitate*, see Paola Pirzio, "Note sulle tre redazioni del *De subtilitate* di Girolamo Cardano," in *Girolamo Cardano*, ed. Baldi and Canziani, 169–79; and Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 163–69. On the success of *De subtilitate*, like that of *De rerum varietate*, see Larder, "The Editions of Cardanus' *De rerum varietate*."

[74] Ian Maclean, "Montaigne, Cardanus: The Reading of Subtlety/The Subtlety of Reading," *French Studies* 37 (1983): 143–56.

[75] See above, in text at notes 5 and 6. Eckman, *Jerome Cardan*, 31.

already published some twenty books.[76] Cardano clearly tried to keep track of who was reading his works, although such was his fame that many who lacked access to the original knew his work at second hand. He wrote that he could not tell whether he was most read in his own works, or in the works of other people.[77] At one point in the *De vita propria* he considered it worthwhile to provide a long list of "those in whose works I have been included with honourable mention." The list runs to seventy-three names including Andreas Vesalius, Konrad Gesner, Christoph Clavius, Daniele Barbaro, Gemma Frisius, and Philipp Melanchthon. Cardano also noted those who held an unfavourable opinion of him, including Leonhart Fuchs, François de Foix, duc de Candale, and of course, Niccolò Tartaglia and Scaliger. Cardano's list could easily be extended by including those who continued to cite or even discuss his ideas long after his death. Subsequent verdicts naturally vary, but it seems fair to say that Cardano was usually used as a target for criticism, and used by other writers to show how their own philosophies were superior to his.

The most notable, and one of the earliest, critics of this kind was, of course, Scaliger, then an established and prominent neo-Aristotelian scholar. His was "the most savage book review in the bitter annals of literary invective,"[78] and perhaps the only one ever to be longer than the book it examined. Cardano attached to the 1560 edition of *De subtilitate* a rejoinder to the main criticisms of Scaliger. However, as Maclean has pointed out, "Scaliger has a well-defined place in the intellectual pantheon of Continental universities, whereas Cardano is either forgotten or seen as marginal to intellectual debate." The reason for this is not hard to fathom. Scaliger's massive critique, compendious in its own right, came to be regarded, especially in German universities, not so much as a refutation of Cardano as a handy re-statement of orthodox Aristotelianism.

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[76] Reckoning the score is complex, since some works already written were never printed till the appearance of his *Opera omnia* long after his death, and some were adapted and formed components of later works. For details see Maclean, ed., *Girolamo Cardano, De libris propriis.*

[77] Morley, *Life of Girolamo Cardano*, 2: 60. Cardano was also concerned to write works that would help to perpetuate his name by being widely read. See Cardan, *The Book of my Life*, 32–33; and Maclean, ed., *Girolamo Cardano, De libris propriis*, 39.

[78] Grafton, *Cardano's Cosmos,* 4. The "review" is J. C. Scaliger, *Exercitationes.* For a searching discussion of the interface between reviewer and reviewed in this instance, see Maclean, "Interpretation of Natural Signs." Morley, *Life of Jerome Cardan*, 2: 169–85, presents an account of Scaliger, but as might be expected, is a warm supporter of Cardano in the contention between the two men. Scaliger had his own critics; Charles Nisard (*Les gladiateurs de la république des lettres*, 371) ridiculed Scaliger's attack on "le pauvre Cardan"; while George Saintsbury (*History of Criticism and Literary Taste in Europe*, 3 vols. [Edinburgh: Blackwood, 1905], 2: 12) pointed out that he was at times regarded as a pedant inordinately critical of Homer, while over-fond of Vergil (but Saintsbury made no mention of his attack on Cardano).

Scaliger's *Exercitationes* became, in Maclean's words, "a useful textbook for university institutions, which still maintained a solid core of peripatetic teaching on their syllabuses."[79]

Francis Bacon, never in danger of over-estimating the importance of his near contemporaries, was also critical, although he did at least include Cardano in august company:

> So in natural history, we see there hath not been that choice and judgment used as ought to have been; as may appear in the writings of Plinius, Cardanus, Albertus, and divers of the Arabians, being fraught with much fabulous matter, a great part not only untried, but notoriously untrue, to the great derogation of the credit of natural philosophy with the grave and sober kind of wits: wherein the wisdom and integrity of Aristotle is worthy to be observed.[80]

Like Bacon, Sir Thomas Browne (1605–1682), later in the seventeenth century, saw Cardano as a great collector of information, but insufficiently cautious in his appraisal of it:

> We had almost forgot Jeronymus Cardanus, that famous physician of Milan, a great enquirer of truth, but too greedy a receiver of it. He hath left many excellent discourses, medical, natural, and astrological; the most suspicious[81] are those two he wrote by admonition in a dream, that is, *De subtilitate* and *Varietate rerum*. Assuredly this learned man hath taken many things upon trust, and although he examined some, hath let slip many others. He is of singular use unto a prudent reader; but unto him that only desireth *hoties*,[82] or to replenish his head with varieties, like many others before related, either in the original or confirmation, he may become no small occasion of error.[83]

Robert Burton (1577–1640), whose *Anatomy of Melancholy* (1621) assembled a literary cosmos full of *hoties*, a compendium of everything, cited Cardano some 128 times. The two men were alike in their boundless appetite for the literature of the past, but Cardano was the more wide-ranging, and in the end the more comprehensive. The ranks of those who discussed his work, like Cardano's own

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[79] Maclean, "The Interpretation of Natural Signs," 234. But note that Maclean also points out (233) that many student dissertations exposed "Scaliger's oversimplification and polemical misrepresentation of Aristotle."

[80] Francis Bacon, *Advancement of Learning* (London, 1605), IV, 10.

[81] The meaning of this word in the author's time is the same as now.

[82] This is a contrived plural of the Greek words ὅ τι "what is it?" used to refer to statements of fact lacking supporting arguments to vouch for their truth.

[83] Sir Thomas Browne, *Pseudodoxia epidemica* (London, 1650), Book I, chap. 8.

discussion of subtlety, could easily be extended almost without end, and so, like Cardano, we must "put a limit to it."[84]

The contents of *De subtilitate* constitute a very wide range. Cardano's "was the universal mentality to which no branch of learning was inaccessible."[85] It opens with the inanimate constituents of the world and their behaviour—basic principles, matter, form, motion and place, the elements—and concludes its upward path with God and the Universe. In between are ranged heaven, light, mixed substances and mixtures, metals, rocks, plants, animals, man, the senses, the soul and the intellect, the so-called "useless subtleties" (a curious repository of odd phenomena, games, and a serious marshalling of Euclidean theorems), the sciences (including some more weighty geometry), the arts and their products, marvels of diverse nature such as acrobatics and conjuring, demons, and primary substances or faults (the latter appear to be phenomena that mislead the mind). Even a method of inducing local anaesthesia finds a place,[86] and Maclean notes the presence of topics such as how to beget male children, how to make an elixir devised by Cardano's father that would ensure long life and prevent greying hair, how a siphon works, why the stars sparkle, why a rose has thorns, why bastards are more robust than legitimate children, and why philosophers are melancholic.[87] In short, it amply justifies its modern estimate in the *Dizionario biografico degli Italiani* as "a sort of hulking encyclopaedia of the natural sciences which contains a little of everything: from cosmology to the construction of machinery; from the laws of mechanics to cryptology; from the application of the natural sciences to the accursed influence of demons."[88] Given this immense range, encompassing many things that were excluded from orthodox natural philosophy, Cardano and his most important book deserve to find a much more prominent place in current historiographies, whether concerned with the breakdown of the disciplinary separation between natural philosophy and the mathematical sciences,[89] the role of the occult in the origins of modern science,[90] the origins of empiricism, relations

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[84] Cardano, *De subtilitate*, Bk XXI, 1264 (1560).

[85] Gliozzi, "Cardano, Girolamo," in *DSB*, 3: 65.

[86] In Book VII, 499 (1560).

[87] Maclean, "Interpretation of Natural Signs," 232.

[88] "Una sorta di mastodontica enciclopedia delle scienze naturali che contiene un po' di tutto: dalla cosmologia alla costruzione di macchine; dalle leggi della meccanica alla criptologia; dall' utilità delle scienze della natura al nefasto influsso di demonium": G. Gliozzi, s.v. "Cardano, Gerolamo," in *DBI*, 19: 761.

[89] See text at notes 29 and 30.

[90] On which, see, for example, John Henry, "The Fragmentation of the Occult and the Decline of Magic," *History of Science* 46 (2008): 1–48.

between science and religion,[91] or the history of the book.[92] As Anthony Grafton has rightly said, the *De subtilitate* is a "great and bizarre book."[93]

The Publishing History of *De subtilitate* and This Edition

De subtilitate first appeared in folio from the famous press of Johannes Petreius in Nuremberg in 1550.[94] Later that same year the folio edition was reprinted in Paris, and octavo editions appeared the following year from two separate publishers in Paris and one in Lyon.[95] It is clear that Cardano regarded it as one of his most important works, and therefore (as was his tendency), he could not forbear from adding to it. Two expanded editions appeared in 1554. The first, about a third as long again as the 1550 edition, appeared in octavo from Lyon in 1554; while the second, about half as long again, appeared in folio from Basel.[96] Both of these were subsequently reprinted, even after they had been superseded by another expanded edition—the last edition to be prepared by Cardano himself. This was the octavo edition published at Basel in 1560.[97]

Although the majority of differences between the 1560 edition and the 1550 and 1554 versions were simply additions, there were some cuts and some revised passages. It is assumed that these cuts and revisions were made as a result of fears about the unwelcome attention of the Inquisition, or in response to what Cardano acknowledged as telling critiques, or perhaps serious misrepresentations,

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[91] See text at notes 36 to 46.

[92] See text at notes 47–52.

[93] Grafton, *Cardano's Cosmos*, 161.

[94] Petreius is famous, of course, for publishing Nicholas Copernicus, *De revolutionibus orbium coelestium* (Nuremberg, 1543).

[95] *Hieronymi Cardani medici mediolanensis De subtilitate libri XXI . . . Norimbergae apud Ioh. Petreium, iam primo impressum. Anno MDL.* Followed by . . . *Parisiis. Ex officina Michaelis Fezandat & Roberti Granion . . . 1550.* Then: *Parisiis, apud Dupuys 1551*; *Lugduni. Apud Gulielmum Rouillium . . . 1551*; and *Parisiis. Ex officina Michaelis Fezandat & Roberti Granion . . . 1551.* For fuller details on the editions of *De subtilitate* see Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 163–69; and Maclean, *Giordano Cardano, De libris propriis*, 83–85.

[96] *Hieronymi Cardani medici mediolanensis De subtilitate libri XXI. Nunc demum ab ipso authore recogniti atque perfecti* (Lyon: Gulielmus Rovillius, 1554). *Hieronymi Cardani medici mediolanensis De subtilitate libri XXI. Nunc demum ab ipso authore recogniti atque perfecti* (Basel: Ludovicus Lucius, 1554).

[97] *Hieronymi Cardani medici mediolanensis De subtilitate libri XXI. Ab authore plusquam mille locis illustrati, nonnullis etiam cum additionibus . . .* (Basel: Officina Petrina, 1560).

by Julius Caesar Scaliger.[98] It is always possible, however, that, in some cases at least, Cardano simply changed his mind about some of the things he had written earlier. A posthumous edition, published in folio in Basel in 1582, extended the 1560 edition by reinstating at least some of the excised material. It is possible that this was prepared by Cardano's former student Rodolfo Silvestri (to whom Cardano had bequeathed his papers), but the historical impact of this edition has yet to be assessed. It is possible that it formed the basis of the version of *De subtilitate* which appeared in Cardano's *Opera omnia* in 1663,[99] but by then Cardano's influence, along with that of other Renaissance occult philosophers, would have been in steep decline.

The nature and significance of the changes in the three main recensions of the *De subtilitate* (Nuremberg 1550, Basel 1554, and Basel 1560) must await a critical edition, detailing all the changes. A start has been made on this by Elio Nenci, but so far only the first eight books have been covered.[100] The principal aim of this edition, by contrast, is simply to provide a readable translation of the final version of the book that was revised and prepared for publication by Cardano himself. The following translation, therefore, is based on the 1560 edition published at Basel; it is the first complete translation into English.[101] There has been no attempt to collate every minor change across the three recensions, but significant differences (constituting passages rather than words) have been indicated throughout to help those whose chief interest is in the development of Cardano's thought. It is hoped, however, that these indications (for the most part confined to footnotes) will not break up the text for those who simply wish to acquaint themselves with the substantive content of one of the most important and influential books of the late Renaissance.

Although this edition does not include Cardano's original Latin, this is now readily available, and easy to consult, thanks to the internet. Indeed, all three of the major recensions are available online. The first edition of 1550 is available

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[98] Schütze draws attention to a passage in the 1554 edition which seems to suggest that all religions are equally justified, but which was cut from the 1560 edition. Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 164, n. 11. Certainly, the 1560 edition also included, as an extensive addition, a response to Scaliger: *Apologia adversus calumniatorem.* Scaliger's critique appeared in 1557 as *Exotericarum exercitationum liber quintus decimus.* Scaliger seems to have used the first edition of *De subtilitate* (1550).

[99] But Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 165, implies that the *Opera omnia* version was simply based on the Basel 1560 edition.

[100] Cardano, *De Subtilitate, Edizion critica (Tomo I, Libri I-VIII)*, ed. Nenci.

[101] Previously, the only part of the *De subtilitate* available in English was Book I. See Cass, "The First Book of Jerome Cardan's *De subtilitate*" (below, n. 106) More recently a French translation of the first four books has been presented in a Ph.D. thesis: Maïlis Paire, "Edition traduite et commentée des quatre premiers livres du 'De subtilitate' de Jerome Cardan" (Ph.D. diss., Université Jean Moulin de Lyon, 2004).

through Gallica, the digital library of the Bibliothèque nationale de France.[102] The longer of the two extended editions that appeared in 1554 is available from the Istituto e Museo di Storia delle Scienze in Florence.[103] The edition used here, Basel 1560, is available in a very high quality reproduction from the Digital Collections of the Bayerische Staatsbibliothek in Munich.[104] It is perhaps also worth mentioning that Cardano's *Opera omnia* (Lyon, 1663) are also available online, on the Girolamo Cardano site maintained by the Università degli Studi, Milan.[105]

In the present edition, the pagination of the Basel 1560 edition, and of the *Opera omnia* (1663) edition, are indicated throughout. It is a comparatively easy matter, therefore, to find a particular location, and consult the original Latin, in either of these editions. The start of pages of the Basel 1560 edition are indicated throughout preceded by an ampersand; like so: &230. The start of pages of the *Opera omnia* edition appear simply in square brackets; like so: [562].

In the annotations, "*OO* 116," for example, refers to page 116 in vol. III of the *Opera omnia* edition—that is the volume of the *Opera* in which *De subtilitate* is included. References to all other volumes of the *Opera* include the volume no.; for example: *OO* 4: 245.

The only previously available translation of any part into English is that of Myrtle Cass (1934), which covers Book I only, and the name "Cass" in the notes relates to her work. "Nenci" in the notes refers to Elio Nenci's critical edition of the first eight books of *De subtilitate.*[106]

Illustrations. These have been copied from the *Opera omnia* edition, apart from a few cases where some gain in clarity was obtained by copying from some other edition. It is unfortunate that the quality of the woodcuts is generally so poor, at a time when Vesalius (1543) produced superb woodcuts; but as Arber remarks, when Leonardo da Vinci was at his peak, his superb drawings coexisted with rough and crude woodcuts in a herbal of the time.[107] These woodcuts

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[102] http://gallica.bnf.fr/ark:/12148/bpt6k52358m.image.r=De+subtilitate

[103] http://fermi.imss.fi.it/rd/bd?

[104] http://daten.digitale-sammlungen.de/~db/0003/bsb00032754/images/

[105] http://www.cardano.unimi.it/testi/opera.html The URL for the Cardano site is: http://www.cardano.unimi.it/

[106] Myrtle Marguerite Cass, "The First Book of Jerome Cardan's *De subtilitate*, Translated from the Original Latin with Text, Introduction, and Commentary" (Ph.D. diss. Columbia University, 1934). Girolamo Cardano, *De Subtilitate, Edizione critica (Tomo I, Libri I-VIII)*, ed. Elio Nenci (Rome: Franco Angeli, 2004).

[107] Agnes Arber, *Herbals*, 3rd ed. (Cambridge: Cambridge University Press, 1988), 202.

"tended to enforce a relatively coarse style of drawing,"[108] and copper only entered the lists at the end of the sixteenth century.

[108] Martin J. S. Rudwick, *The Meaning of Fossils: Episodes in the History of Palaeontology*, 2nd ed. (Chicago: University of Chicago Press,1985), 7.

On Subtlety, in 21 Books by Jerome Cardano, Physician of Milan

Author's Poem[1]

The earth will not cover me over, but I will be snatched up to high heaven and live in distinction in the learned mouths of men. Whatever Phoebus looks upon in the years to come will recognise the Cardanos, and my name, forever.

Dedication of the 1550 edition[2]

To the most illustrious and excellent Ferrando Gonzaga,[3] Prince of Malfeta,[4]

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[1] This poem is included in the 1560 edition, but not in Nenci's edition nor the *Opera omnia* edition of 1663; volume III of that 1663 edition is cited occasionally here as *OO* from now on. Any other volume of that edition is cited as, for instance, *OO*1.

[2] The text of this dedication has been drawn from Nenci's edition of *De Subtilitate* (see Bibliography), 45–46.

[3] Ferrando (or Ferrante) Gonzaga (1507–1557) was the son of Francesco II and Isabella d'Este; a soldier with Charles V and very successful against France at first. In 1539 became Conte di Guastalla (Cardano's "Vastalla," and also known as "Guastalla"; it is about 30 km northeast of Parma in northern Italy). He visited Britain in 1543 on behalf of Charles V, seeking the assistance of Henry VIII against France, and in fact Henry undertook to invade France. See *Dizionario biografico degli italiani* (Rome: Istituto della Enciclopedia Italiana, 1960-), 57: 734–44. He was the arbiter at the celebrated contest between Tartaglia and (on Cardano's behalf) Ferrara, on 10 August 1548. In 1546 he became Duke of Milan, Lieutenant-Governor for Spain, but lost this position in 1554 and went back to Guastalla. Died 1557, leaving Guastalla to his first-born, Don Cesare (1536–1575, who was called "Cesare" in honour of the Emperor Charles V).

[4] Mercator's *Atlas* of 1595 indicates a promontory of Malfeta on the south east coast of Italy south of the Gulf of Taranto, and a town of Malſeta on the east coast of Italy approximately on the latitude of Rome.

Duke of Arrian,[5] lord of Vastalla,[6] in the province of the Milanese, and Prefect of the armies of the Emperor,[7] Jerome Cardano, physician of Milan, sends greeting.

Illustrious Prince, nearly all races in our age revere God; but none of them except the wise alone do what it is best to do, and do it for the best of reasons; some worship God because they hope for many benefits through revering Him, and fear great evils through scorning Him. And so this is not love nor reverence, but rather hope or fear. And though this hope or fear would not be in vain (they are surely fruitless if directed to the consequences for mortals, not for the rewards of the soul), still they would be no ideal reason for an ideal action. And now, in my view, not only is there no right basis in them for divine worship, but there is even an empty one. There are other people who worship God because it is their own habit or that of others; and though they deserve no praise at all, still the people who worship God simply from fear of the laws, and are undoubtedly immoral, are less blameworthy. And there are folk such as priests who profit from having worshipped God. Others use His name to seize some reputation for morality. And so they should be called mercenaries, like those of the past, if they do so for no other cause. Hence it is not I now, but truth itself that has condemned them by calling them hypocrites. Some other people, ambitious beyond the rest, worship God because they suppose that they are of special concern to Him. In their case you will have given them less praise for worshipping Him than blame for promising so much on their own account through a preconceived view.

So it is the wise only that revere and rightly worship God nevertheless, because He is very good and eminent, even though He were not providing us with any benefit. For it is by cultivating the best people and holding the evil ones in odium that we are made better; because He is the basis of all our benefits together, whether He does everything as its originator, or (as philosophers would have it) controls and regulates all that now exists of itself.

I think that wise men should preserve a similar principle in extolling Princes; that is, to extol only those who are excellent, and who deserve very well of their native land. And so since I recognised you as excellent, very just and very brave, since I noted your services to my fatherland, I thought you worthy of every kind of praise which was reckoned greatest among the rest of us: the prowess of your ancestors, the feats, the power, the distinction; you who have reckoned as lords of Milan not just your father and grandfather, but your great-grandfathers and more distant ancestors, making you now the tenth in the sequence. I will refrain

[5] Ariano (present-day spelling) is about 90 km southwest of Venice, near Rovigo (*Orbis Latinus*).

[6] Vastalla, also known as "Guastalla," is about 30 km northeast of Parma in northern Italy.

[7] "Caesar," i.e. Charles V, who was Holy Roman Emperor from 1519 to 1557.

from proclaiming this, in case perhaps you say as Ulysses did, "I find it hard to call mine my race and my ancestors and what we have not ourselves done."[8]

But, O Prince, this is not your primary source of praise, you who have progressively embellished the military glory of your family, unequalled of its kind, taken over from your ancestors; by your valour you have brought the best-fortified towns of France into your power, though you are as outstanding in the arts of peace as in those of war; by your virtue you won over Henry[9] King of England to the Emperor Charles[10] so fully that among other instances of confidence and friendship the King on his deathbed left Charles as guardian to his only son[11] and heir. By your integrity while ruler of Sicily and Milan you restored the age of Saturn,[12] so that both provinces abandoned the era of iron and enjoy that of gold.

Am I to say a little, when there is so much to say? Or will you feel yourself bound by some unspoken hint referring to what the great nobility of your mind impelled you to do? Perish the thought. Then someone will say this: what have you to offer worthy of so great a Prince? I could not offer too much. Arithmetic is actually very pleasant to study, of exceptional inventiveness, but about things of which plumper people say, "What is the point of such a great spectacle of human genius?" Thus we jest about geometry,[13] and about our writings upon the immortality of the soul.[14] I have pursued astronomy with marvellous discoveries, both novel and true,[15] but now by a failing of elderly people they have acquired so much disrepute that the word "discipline" removes more authority from my book than my name adds to it. The medical writings are extracted from the writings

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[8] Ovid, *Metamorphoses* 13. 140.

[9] Henry VIII, died 1547.

[10] Charles V, Holy Roman Emperor.

[11] Edward VI (1537–1553). His tutors before he reached the throne were Sir John Cheke, who incidentally taught him Greek, and Richard Cox. After his accession to the throne, his brother-in-law, Edward Seymour, Earl of Hertford, became lord protector shortly after the new reign began (*Encyclopedia Britannica*, 2003 ed.). Henry VIII had not named a protector in his own lifetime; the office "had unhappy overtones" (*Oxford Dictionary of National Biography*, 26: 546b; entry on Henry VIII). This assertion about the Emperor Charles V seems an improbable political fiction; no reference to it can be found in the *DNB*'s entries on Henry or on Edward, nor in Henry VIII's will at http://www.constitution.org/sech/sech_076.txt.

[12] The allusion is to Vergil, *Eclogue* 4. 6: "redeunt Saturnia regna"—a classic figure of rebirth and renewal.

[13] Cardano published several works on geometry; for details see Ian Maclean, *Girolamo Cardano, De libris propriis: The Editions of 1544, 1550, 1557, 1562, with Supplementary Material* (Milan: Franco Angeli, 2004).

[14] *De immortalitate animarum*; published 1545. See Maclean, *De libris propriis*, M55.

[15] Among Cardano's publications with astronomical content is his *Aphorismorum astronomicorum segmenta* VII, published in 1547 (Maclean, *De libris propriis*, M79).

of others,[16] the books *De Consolatione*[17] are all unsuccessful, those *De Sapientia*[18] are full of errors. And overall, as folk say, they are all of a definite kind, and no good to anyone, apart from the medical ones, of which a tiny part has so far been issued. Let him issue, folk say, some new and subtle discovery, to be of use to the human race, and good for providing wealth too.

This is no time, I must say, for discussing these individual slanders. One must give in even to one's enemies, and to those who fall in with their conditions, when the hook of all verbal abuse may be taken out on conditions which are in our power. And the lesson I will teach them is this, that it is not my energy that was lacking, but my will.

Meanwhile, my best effort is to be offered, to a person of most deserving service to my country. I was looking all around for something fit for such an outstanding Prince, and no indication was occurring to me of a nobler treatise,[19] or one of more use to the human race, than this very one, one embracing everything at once and disclosing it by reliable argument; I was in fact afraid that the material itself might be covered without demonstration, as in the books *De rerum varietate*,[20] true though they were; and with one or other among so many experiments not prospering, confidence in this book too would be withdrawn, as it was in Pliny too.

But over Pliny, liar though he often was, there stand guard the authority of antiquity and of the history of his time, and now that of his trustworthiness, and a plan of speaking suited to the material in hand. If I have lost my view of the truth, with what can I defend my book? But even if you were to support my view of the truth by testing it, it cannot be securely held without knowledge of the cause. When I grasped how very difficult the undertaking was, in demonstrating causes I counterbalanced this obscurity by simple easy language, to avoid boring my audience, and to make it appear that I had aimed to write for myself alone. So I dedicate and present this book to you, most humane Prince, whatever its merits, and I pray for the good fortune and long life of Aloisius[21] the mainstay of your family; in this way the interests of the Emperor will be protected. Farewell.

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[16] "Medica ex aliorum scripta excerpta sunt": the text (Nenci, 46) appears corrupt here.

[17] Originally published in 1542 (Maclean, *De libris propriis*, M46).

[18] Originally published in 1544 (Maclean, *De libris propriis*, M47).

[19] "tractatio."

[20] Originally published in 1557 (Maclean, *De libris propriis*, M104).

[21] "Aloisius"; this is Gian Francesco Alois (ca. 1510–1564), a close friend of humanists and poets around Juan de Valdes. Cardano here calls him "auctor," a word with a wide range of meanings, here rendered as "mainstay." But Cardano's good wishes for long life were ineffective, since Alois was condemned and burnt for his irregular views.

Dedication of the 1554 edition[22]

Ferrando Gonzaga, Prince of Malfeta,[23] Duke of Arrian,[24] Lord of Vastalla[25] in the province of the Milanese, and Prefect of the armies of the Emperor.[26] Most distinguished Prince, when I ponder your services to our country, and your virtue, your notable wisdom displayed in times of war and of peace, your courage in peril, your faithfulness to your promises, I certainly feel a great debt to you on this account. I shall not mention what used to be reckoned the greatest thing in the case of others — I mean the virtue of their ancestors, their achievements, their power, their renown — since you have had Lords of Mantua not just as your father, or grandfather, but also as great-grandfathers, great-great-grandfathers and great-great-great-grandfathers, so that you are now the tenth in line. But that, greatest Prince, is not your major distinction; you have embellished the military glory inherited from your ancestors further still, you have captured so many cities, you have presided successfully over military operations so often, you have won over so many friends for Caesar.

But I leave out what commands the utmost praise, matters that I cannot recount without disturbing some people in the course of such a savage war and in such a time of disaster. I shall confine myself to the virtues and deeds of peace itself. Though our province has had such numerous Princes and prefects, it has been conscious of the good deeds of Ferrando Gonzaga alone, it has experienced his justice, it will ever be obliged to revere his memory, even if (perish the thought) it was inclined to ingratitude. You have fortified the city with walls like Babylon's, you have improved its citadel, you have made both of them impregnable and very beautiful. You have decorated and improved its streets, houses, and dwellings to such effect that what you took over as brickwork is now marble only a few years later, for us to admire.[27] Turning then to our behaviour, how much improvement you have achieved! How many abuses you have removed! How many very wholesome laws you have devised! And so, feeling that on this account alone I was vastly indebted to your virtue, and totally indebted to your kindnesses, I was eager to salute you with some service. And though many possibilities were occurring to me, none seemed more appropriate than to revise again, purify, and complete what I had already started and had dedicated to your name. For when Iohannes Petreius, printer at Nuremberg (a man born for the

[22] This earlier Dedication, in the 1554 edition, is included by Nenci and is dated 1552, from Paris.

[23] On Malfeta see n. 4 above. On Ferrano Gonzaga see n. 3 above.

[24] On Ariano see n. 5 above.

[25] On Vastalla see n. 6 above.

[26] On "Caesar" see n. 7 above.

[27] The statement that Augustus found Rome brick and made it marble appears in Suetonius (*Divus Augustus*, 28. 3. 167).

advancement of learning and hence worthy of immortality),[28] had passed away after the publication of these books, I took care that they should make their public appearance under your name; I had worked out barely an outline, and I completed them over an eight-month span. They had been improved and augmented throughout three years. I thought it would be safer that what was being dedicated to your name was something whose general popularity I had sampled. And in that way I would be readily able to appreciate what its future popularity would be too. I know there will be plenty of people unable to produce anything better and incompletely comprehending what I shall write, because many will read it, but few or none of them will be capable of appreciating everything written here. Again, as there is a great deal below the surface that matters more than what is covered explicitly, people may try to contradict me in a few details, arguing perhaps that they think I am differing from Aristotle. For mankind is at present so sensitive that they prefer to deviate from the truth, from the evidence of their senses, from experience, from reason, and from everything, rather than from the authority of that man. And though they respect Galen as contradicting Aristotle in not such obvious and numerous points, fault is found with me for seeking to desert him on such clear-cut arguments and reliable experience, in one or two matters (there are no more in which I can be seen at odds with Aristotle). Though over these few matters it is not even him I would abandon either, but his expositors, who have failed to follow his view, if I may so put it. And they do not want cockroaches[29] and the cave of Attica[30] to do me any good either. Many people will bring up more extraordinary matters, as if they were off to battle with shades and ghosts, using men and a line of battle. For indeed genuine experience and trifling tales are quite different explanations which can be launched into the infinite. This is so true that Pliny himself who wrote this, being much more modest, would reject Albertus[31] and jeer at him—and would trust only the account of those who have made contact with Rome.[32] And so the people who battle against

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[28] He also published the *De Revolutionibus Orbium Coelestium* of Nicolaus Copernicus (1543).

[29] "blattas"; in his *Nat. Hist.*, Pliny refers to these a number of times (11.98, 25.108, 20.171, 29.139 and 30.131). All these references are to medicinal or practical uses of cockroaches, but not with any obvious relevance here.

[30] Reference unclear. It is curious that Pausanias, who takes a notable interest in caves at various places mentioned in his work, includes none in Attica. The most notable cave in antiquity was perhaps the Corycian, but it was in Cilicia, not in Attica; there is much more on caves in Book II of the present work, 208–10 (1560). Search of Pliny's *Nat. Hist.* under *specus*, *spelunca* has not succeeded. There is here perhaps a reference to Plato's "cave" in his *Republic* (514a), an allegory of human ignorance with an account of release from it.

[31] On Albertus Magnus see n. 94 below.

[32] Reference not traced, on the assumption that this must be Pliny the Elder, author of the *Natural History*.

proofs, experience, and the truth look to me like those who have learnt only how to demolish walls, and not how to put one stone upon another for building purposes. Those who really suppose that I contradict Aristotle would display obvious hatred of the truth and mental inertia. But those who raise larger issues display their simplicity, taking it that there is no difference between purely and simply promising something, and teaching and proving it by reliable argument.

I turn again to you, you who have run the kingdom of Sicily with such great restraint, you who have given lustre to our city, you who wage war with vigour and wisdom, you who have ever supported genuine virtue; I dedicate and present this work, such as it may be, to you, most humane of Princes. I wish for the happiness and long life of Aloysius,[33] the author in your retinue, and hope that you will be able to do for this work the loyal service you have paid to your master, the Emperor. Farewell.

April 21st, 1552. At Paris, while travelling.

Dedication of the 1560 edition

[353] Jerome Cardano of Milan, physician, greets the most distinguished and excellent Don Consalvo Ferrando, Prince of Cordoba,[34] Suessa,[35] and the New World, Lord of Capra, legate of the King of Spain, and commander of armies.[36]

As I set about my complete account of the universe in this single volume, Magnanimous Prince—a task clearly beyond my powers—I hoped to bring it to a conclusion, but while already beginning it, I was more influenced by scruples that deterred me from abandoning it. What could be more tangled in the multitude and diversity of subjects, or more incomprehensible in its argument? I have attacked my task with so much hope that I reckoned that what I was unsure would be praised would surely qualify for pardon if I was in error. And wherever I happened to set a target,[37] I would find I had surpassed it. But since I had discovered myself mistaken in both views, and other people were stipulating with excessive eagerness that I should satisfy everyone, I had to bring out the same work a second and a third time. A second time so as to please my supporters—

[33] On Aloisius see n. 21 above.

[34] City in southern Spain.

[35] Now Sessa Aurunca, about 50 km north of Naples and 10 km from the sea.

[36] This is the undated dedication of the 1560 edition. Don Consalvo Ferrando (or Gonzalo Fernandez) was the grandson of the Don Ferrando Gonzaga to whom earlier editions were dedicated (see above). He became Duke of Milan from 1558 to 1560. Cardano treated him sometime between 1558 and 1562. See Nancy Siraisi, *The Clock and The Mirror: Girolamo Cardano and Renaissance Medicine* (Princeton: Princeton University Press, 1997), 37.

[37] "meta."

and that made me add more than a half part of it, and I also embellished it so far as was possible. I had dedicated both these editions to Don Ferrando Gonzaga, Prince of Malfeta,[38] a man who was occupying the role of legate and prefect of the Emperor[39] in our province, a man certainly of great vigour, and a very experienced soldier, and endowed with every kind of virtue.

But after his death, when I had set about publishing this work for a third time, so as to block the mouth of Cerberus[40] or Hydra,[41] I polished and rubbed and embellished it so much that it looked a quite different book from the two already published. Consequently it could be difficult to set a name[42] to the new work, with the man now dead; and I had kept my duty to the Gonzaga family and to Don Ferrando continually in mind, and had also given satisfaction with my exceptional praises of the Emperor's son (a most noble-spirited Prince) in another book. So I decided to dedicate this one as a sort of debt to you, not just because you have taken over the legate's position and the prefecture and also the benefits conferred upon me, but also because I regard you as the most distinguished and best of men, with due respect to others.[43]

In mentioning this I run [354]twin risks: that of flattery, and of being thought to utter what everyone knows perfectly well. However, I felt it better to run both these risks than to incur any suspicion of ingratitude, particularly because what is now very well known must, if not written down, be ultimately rendered unknown to posterity through the impact of time. So if we consider illustriousness, who can properly be compared to you? Your original fatherland was Cordoba, the Cordoba that on its own has fathered[44] two very great and wise men — Seneca[45] and Averroes[46] — so that on that achievement alone, the city is not seen as seeking to compete with the whole of Spain in glory, but rather as giving lustre to Spain single-handed. The result is that for wisdom the name of Spain is known

[38] See n. 22 above.

[39] The Holy Roman Emperor Charles V.

[40] From Homer onward, the three-headed (or, according to Hesiod, fifty-headed) dog guarding the entrance to Hades, the underworld. See H. D. Brumble, *Classical Myths and Legends in the Middle Ages and the Renaissance* (Westport, CT: Greenwood Press, 1998), 88–89.

[41] A mythical snake-like creature killed by Hercules. Its haunt was at Lerna in Argolis in the Peloponnese of Greece. See Brumble, *Myths*, 173–74.

[42] "nuncupari."

[43] "pace aliorum dictum sit."

[44] "peperit,"

[45] Roman politician, playwright, and Stoic philosopher (ca. A.D. 1–65).

[46] The most famous of the mediaeval Islamic philosophers, born in Córdoba, Southern Spain. He was a judge successively at Córdoba, Seville, and in Morocco, and wrote on jurisprudence and medicine. In 1182 he became court physician to Caliph Abu Yusuf, but in 1185 was banished. His *Commentaries on Aristotle* were his most important works.

to all the world through these two most productive talents,[47] both begotten in the city of Cordoba. You are the offspring of parents both of them of the utmost lustre, and they were descended from the same Prince who freed Cordoba not only from barbarians but also from wild Africans and devotees of the Mohammedan superstition. And so from that notable siege[48] they received for the future the name of "Cordobans."[49] Thus what the poet wrote about Ulysses suits you nicely: "God is in both parents."[50] He actually used to trace his origin along the paternal and maternal line, but along the fabulous account traced it from Jupiter. You are really descended on both sides from someone who distinguished himself both by his deeds and by his piety. That noble stock divided into two main trunks; from one sprang Don Luisio Ferrando your father, and he was the son of Don Diegho, the lord of Capra. He was nominated as Royal Deputy,[51] but being overtaken by death at Naples, could not complete the task allotted to him. His own father was another Don Dieghus, your great-grandfather, the man who with five hundred knights provided by his subjects overthrew and drove off the King of Betica,[52] who was besieging the citadel of Lucena[53] with five thousand knights — the King himself was captured, and the citadel and your great-grandfather's associates penned up in it were freed. This is why to this day a depiction of twenty-two banners and of the Moorish king in chains appears on the arms of your family on your father's side.

But much more splendid are the deeds of Don Consalvus Ferrandus,[54] the parent of Helvira your mother. If they had not happened within our lifetime, they would have been so unbelievable as to seem fabulous. And it is from one of them that originated all the military lore, all the leaders' noble-mindedness, all the dedication of the defenders of Christianity that blazed forth — under him served

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47 "ingenia."

48 Córdoba was captured by Ferdinand III of Castile from the Moors in the thirteenth century after a four-year-long siege.

49 The words "cum è familia castri essent," appear here in the 1560 edition (as they do in *OO*, but the Dedications of the other editions consulted are to other noblemen and are entirely different), but I cannot translate them. "Castrum," meaning a camp, is normally written in the plural, and does not make manifest sense anyway. A link to a family with the surname of de Castro might be indicated here.

50 "Deus est in utroque parente." This concept is evidently derived from what Ulysses says in Ovid, *Metamorphoses*, 13. 144: "I declare that Jupiter was the founder of my family also . . . for my father, Laertes, was the son of Arcesius, and Arcesius' father was Jupiter . . . Then again, on my mother's side, I have a second claim to noble descent, through my connection with Mercury. Both my parents number a god among their ancestors."

51 "Prorex."

52 The region in Spain round the river Guadalquivir, in antiquity known as the Baetis.

53 In Spain, about half way between Malaga and Cordoba.

54 This man as Gonsalvo Ferdinando originated from Cordova in Spain.

firstly Antonius Leva, who freed our fatherland from all its enemies by such a number of celebrated deeds—then Prosper Colomna,[55] who drove the enemy from Insubria.[56] The Avali[57] were two thunderbolts of war: Petrus Navarra,[58] the man who added a large part of the African coast to the kingdom of Spain and the Christian religion, having driven out the enemy along with their impiety[59]—and Bartolomeus Livianus,[60] a vigorous leader—they taught the art of war.

But where is this going? Surely more important is this, that as a very great king, he presented these men, and also all the other prefects that fought with them, to the towns and districts—Livianum, St Marcum,[61] Olivetum[62] to Navarro, Miletum[63] to Don Diego Mendoza, Avellinum[64] to Don Ioannes Cardona, all these being cities, and in addition notable citadels and districts to Prosperus and Fabricius Colomna,[65] Leva, Andrada, Alveradus, Caravallus,

[55] Prosper Colonna (ca. 1460–1523) in 1523 was made commander of the forces of the Emperor Charles V in Italy, but was defeated by the French and forced back to Milan, where Colonna died in November; the next year the French were driven out of Italy. See *Dizionario biografico degli italiani*, 27: 418–26.

[56] A district north of the Po in Italy, around Milan, which was in classical times the territory of a tribe named the Insubres.

[57] The warlike Avalos family were of Spanish origin, and the most likely candidates here are Alfonso d'Avalos (1502–1546) and Ferdinando Francesco d'Avalos (1489–1525). For details of the family see *Dizionario biografico degli italiani*, 4: 611–37.

[58] Pietro Navarra (1454–1528) was a notable warrior both on land and sea over a period of some forty years in various causes; at one time a price was placed upon his head of 100 ducats if alive, or 50 if dead. He was ultimately executed by the Emperor Charles V. Full details are provided in item 1239 of *Note biografiche di Capitani di Guerra e di Condottieri di Ventura operanti in Italia nel 1330–1550*, available on-line.

[59] In this tortuous sentence ("qui partem magnam orae Africanae Hispanico regno et religioni Christianae simul depulsae cum hostibus impietate adiecit") I have sought to make sense by changing "depulsae" to "depulsa."

[60] Italian general (1451–1515) who was fighting the French in 1503 and defeated the Emperor Maximilian in 1508. Further detail in M. E. Cosenza, *Biographical and Bibliographical Dictionary of Italian Humanists and of the World of Classical Scholarship in Italy, 1300–1800*, 5 vols. (Boston: G. K. Hall, 1962).

[61] There were various places named St Marcum in Italy or Sicily: one in Campania, one in Calabria, and one in Sicily [*Orbis Latinus*].

[62] Now Oliveto dei Pozzilli, Campobosco, Italy [*Orbis Latinus*].

[63] In Calabria in Italy.

[64] Now Avellino, in Campania in Italy.

[65] Fabrizio Colonna (1460–1520) pursued a very distinguished military career, often in association with his brother Prosper, in the course of which he won fifteen battles and lost seven. Full details are provided in item 478 of *Note biografiche di Capitani di Guerra e di Condottieri di Ventura operanti in Italia nel 1330–1550*, available on the Web.

Emanuello, Andrea Capuanus.[66] And he was certainly powerful,[67] since they say that within the two kingdoms of Deticum and Naples, which your grandfather subdued, two hundred cities and seventy villages[68] were added to the kingdom of Spain. I say nothing now about the silver vessels, the gold, money, clothing, which were beyond counting, so much so that at one time he got beyond a hundred thousand crowns in one donation. And the latter, unlike the former, not from the royal liberality but from his own resources; he had in fact accepted as a gift Suessa,[69] Terra Nova, Vestia,[70] Loxa,[71] Aquila,[72] and villages beyond counting along with these, and very extensive regions. And so, just as he had enriched others, he himself was greatly enriched by royal bounty. This man was otherwise famous for a number of victories—a naval one at the bay of Otranto,[73] when the island of Cephalena[74] had also been captured previously and handed over to the Venetians under a treaty, and this is in addition to the victories he had won in the Gaditanus[75] kingdom. He also got the better of the French in battle at numerous [355]places, without ever being wounded or struck, almost through a prodigy of good fortune, or some divine providence, as is related about Skanderbeg[76] too. He was religious, dutiful,[77] continent, so that he never during his so many victories seems to have done wrong to a married woman or virgin for holding out against him.[78] Thus he deserved the name of "Great" given him, a name given to Alexander alone among the Greeks, and to Pompey alone among the Romans. And the more credit to him, because it was enough to have called Alexander and Pompey simply "Great," but it is not enough to have called Consalvus "Great"—call him "Great Leader." As the others stood out amongst

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66 Andrea da Capua pursued a brave military career in Italy from 1495 and died in 1511. Full details are provided in item 368 of *Note biografiche di Capitani di Guerra e di Condottieri di Ventura operanti in Italia nel 1330–1550*, available on the Web.

67 "Et potuit sane . . ."

68 "oppida."

69 See n. 35 above.

70 In Apulia in southern Italy.

71 Now Loja, near Granada in Spain, 30 miles NE of Malaga.

72 District in Italy about 100 km east and a little north of Rome.

73 Hidrodontum in the Latin, in Apulia (southern Italy) [*Orbis Latinus*].

74 Cephalonia, the largest of the Ionian Islands off the western coast of Greece.

75 Of Cadiz, in Spain.

76 Skanderbeg (Georgy Kastrioti, 1405–1468) was "an Albanian of military genius . . . who rallied the Albanian princes and succeeded in driving the [Turkish] occupiers out . . .he frustrated every attempt by the Turks to regain Albania. His unequal fight against the mightiest power of the time won the esteem of Europe." (*New Encyclopedia Britannica*, 14: 6162a)

77 "pius."

78 "pro constanti."

men,[79] so Consalvus did among the leaders themselves—but perhaps too much so. You would do well enough to have been the heir of such virtue, such a name, and such power—but your parents were responsible for your name, fortune for your power, and yourself for your virtue. To be sure, just as the other Marcellus[80] demonstrated that Hannibal could be defeated, you demonstrated that the French could. They, previously unbeaten by so many distinguished Imperial generals, had so severely terrified us that we hardly felt safe even in the middle of our towns. We kept hearing daily that our troops had been routed or captured, our villages and towns brought under the French power. We had forgotten how to win, so that we could never comprehend anything except a loss. You were the first to rid our fatherland of this terror, not only repelling the enemy's weapons, but thrusting our own against him. In fact, they could hardly feel safe and secure in the strongest and best-protected towns. If that most fortunate peace had not been concluded, there was no doubt that under your leadership we would have got more by force than they would have been prepared to hand over by those treaties which suited our King very well. Hurrah that such a store of virtue and good fortune lay with one man, that the invariable victors were being worsted by these same[81] soldiers and their enemies. And the people who used to ride roughshod over other people's frontiers were now at pains to guard their own. In this way, by some deadly talent, the extraordinary good fortune of this nation of yours was always something for the enemies of the Spanish name to fear.

And you distinguished yourself in the arts of peace as much as in those of war—you outdo all others so much in justice, prudence, humanity, liberality, and splendour that Spain's name (notable everywhere else for virtue) grew grander and more attractive through you yourself alone. And I among others can testify to everyone that after idling so long without public occupation under so many Imperial prefects, I was recalled to public service by your encouragement and the Senate's authority, just through your view of my interests—not through my prayers or my ambition. And so I am keen to repay by some service this impressive virtue at home and abroad, in war and in peace, this magnanimity and fame of your ancestors and their deeds, and the kindnesses done me, in addition to notable liberality—so that I can avoid looking quite ungrateful, I hoped to be able to do something as well-judged as dedicating to a most distin-

[79] But Cardano has lost the thread and written "quemadmodum ille inter homines," using the singular "ille."

[80] Marcus Claudius Marcellus pursued a series of successful campaigns against Hannibal and the Carthaginians from 216 to 208 B.C., culminating in his victorious siege of Syracuse, and he earned the title "Sword of Rome."

[81] "Hisdem"—a kind of compromise between "his" and "eisdem"!

guished Prince of comprehensive virtue an enquiry similarly comprehensive.[82] But I did not decide to do this out of misdirected zeal or pointless intention; even if your prosperity and elevated virtue is in no need of support, everything mortal (however great and impressive) requires armour against the onslaught of time. Hence Horace's well-known lines:

> Many a brave man lived before Agamemnon, but all of them are hurried away, without a tear and unknown in their long night, through lack of a dedicated poet. Virtue kept concealed differs little from buried sloth.[83]

And so all wise and celebrated men have made much of this second life, which consists in the memorials of literature. Alexander was greatly distressed because he had not acquired a Homer,[84] and so used to call Achilles alone fortunate. Caesar wrote *Commentaries* on what he had done, and it is certain that Sulla[85] did the same. No prince, no wise man has recoiled from such praise; rather, they all looked for permanent life, either through their historical conquests[86] or through their own efforts. Your grandfather did not neglect this task—he was happy to read carefully the poems written in his praise by Petrus [356]Gravina.[87] And there were plenty of people to put his biography more fully in writing.

We hope the present single volume will be in everyone's hands in future, and as already so many people read it in my lifetime, we have been keen to dedicate your name by it to eternity (so far as we can), and will later be keen to do the same with other written works, so that we can say in the words of a distinguished poet:[88]

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[82] I hope this represents the general sense of a sentence of tortured syntax: "ne omnino ingratus videri possem, non alio sane opportunius posse facere speravi, quam si omnigenae virtutis Principi splendidissimo omnigenam etiam historiam dedicarem."

[83] Horace, *Odes* 4. 9. 25–30: "Vixere fortes ante Agamemnona / Multi, sed omnes illacrimabiles [Cardano spells this "illachrymabiles"] / Urgentur, ignotique longa / Nocte, carent quia vate sacro. / Paulum [Cardano read "Parum"] sepultae distat inertiae / Celata virtus."

[84] That is, someone to write the history of his campaigns.

[85] Roman statesman and general (138–78 B.C.) who led one side in the Civil War of Rome during 88–86 B.C. and became dictator. His *Commentaries* did not survive, except as sources for later writers (Plutarch, Appian, and Livy).

[86] "conquisitis"; the meaning "conquests" of the word in late Latin is attested by DuCange (*Glossarium mediae et infimae Latinitatis*, 2: 510).

[87] Pietro Gravina (1452–1526), a humanist of the sixteenth century, wrote a poem entitled "Consalvo Ferdinando magno invictoque duci Epicum carmen" (Naples, 1532). But in this poem the lines quoted just below in the present work cannot be traced, and these lines may not in fact be by him, and possibly be by Cardano himself.

[88] On the authorship of these lines, see n. 87 above.

"Illustrious offspring of ancient Dukes, engaged in increasing your Spanish dominion, ornament of ancient warfare: if from innate excellence a mind with foreknowledge of the truth foretells anything far ahead, Gonsalvus,[89] we send you this book, as appropriately as we can,[90] as a measure of my confidence. Farewell."

[89] "Consalve."

[90] The likely sense of "quo possumus aptius."

[357] &1 Book I: The Principles, Matter, Form, the Vacuum, the Resistance of Bodies, Natural Motion, and Position.

The aim of our undertaking in this work is to discuss subtlety.[91] It is the feature[92] by which things that can be sensed are grasped with difficulty by the senses, and things that can be understood are grasped with difficulty by the intellect. Hence if items in which subtlety features also present a major undertaking, and are extremely difficult, then what will need to be said about a discussion in which the whole feature of subtlety is for explanation? And the only thing that can appear obvious and easy is this, that in each branch of study it is the most obscure aspect.[93] Also, a greater undertaking remains for us in the discussion of the thing than in the thing itself. In fact the &2 writers labour over four sorts of problem: the obscurity of the topics, doubt in uncertain matters, the revealing of causes, and their correct exposition. So all these problems pile themselves higher in this book. If obscurity gives rise to difficulty, this book picks out only the most difficult items. If it was always hard to attain sure knowledge, what is harder work than this subject?—where I am to have people to avoid, like Pliny and Albertus,[94] who in this field command no confidence, because they tell obvious lies, and I am not to follow them.[95] Yet if everything has not been worked

[91] The interpretation of Cardano's use of the Latin word "subtilitas," translated here and throughout simply as "subtlety," is complex, and the reader is urged to consult the discussion in the Introduction.

[92] "ratio."

[93] "Idque solum apertum et facile videri potest, quod in unaquaque disciplina est obscurissimum."

[94] St Albertus Magnus (ca. 1200–1280) was born in Bavaria and played a leading role in incorporating into scholastic philosophy the substance of Aristotelian writings newly recovered through the Arabic tradition, and in reconciling this with Christian belief.

[95] In the Epistle Dedicatory to the 1550 Nuremberg edition of the present work, Pliny is mentioned as "saepius mentientem"—"often lying."

out to my own high standard, I shall be wasting my effort (as the phrase goes) and my lamp oil.[96]

What am I to say about causes? They should be displayed without any meddling, indeed as if received from some oracle. Trust in oracles used to be maintained without proof—but no trust in us will be maintained, if we have not added proof. The topics that are now for me to expound on my own were completely ignored over so many centuries, even by philosophers aware of the things themselves. Some of them too that have been lacking, or have recently been discovered, either lack names, or the names lack actual things. Further, it is very difficult to invent names for new things, and in a language[97] that is growing elderly. Even when I have found them, I am compelled to add a considered view, so as to avoid the abuse of those who have recently written upon these matters. In the case of the remainder, not even[98] Oedipus himself would satisfy the reader.[99] Since, then, we have embarked on quite a laborious task, just as much usefulness and fame will accrue to the work itself &3 as a reward—but not in proportion to the extent of the labour.[100] Over and above these points, there were some wrongly handled by the ancients. But I do not labour over these, since writers have no authority that ranks with experience.[101] Hence the evidences of difficulty in this discussion are so numerous and so great.

[96] Plautus, *Poenulus* 332: "Tum pol ego et oleum et operam perdidi."—"Then I've lost both my lamp oil and my effort, for sure."—this said by the Maid, who has just been given "greetings of no value" by the sprightly Agorastocles. And Cicero (*Ad familiares*, 7. 1. 3; ed. Shackleton Bailey, 1: 175) remarks that Pompey humorously regarded some athletes as a waste of "opera et oleum," the oil not being "midnight oil" this time but oil for anointing athletes!

[97] Latin, clearly.

[98] The Latin reads "ne"; "ne . . . quidem" is more conventional, but *OLD* endorses the use of "ne" alone, with the meaning shown here.

[99] Oedipus in ancient myth visited Thebes (in Greece) when it was plagued by a monstrous Sphinx which destroyed those who could not solve her riddle. Oedipus solved it, and the Sphinx killed herself. See Brumble, *Myths*, 245–46 .

[100] The Latin here runs: "Itaque cum rem admodum laboriosam aggressi simus, non tamen pro laboris magnitudine, operi ipsi praemii vice utilitatis et gloriae tantundem accedet." It is not easy to interpret, and I have had helpful discussion with Professor John Richardson of the University of Edinburgh. Cass has ". . . nevertheless the completed work will not receive as a reward a degree of usefulness and of commendation proportional to the greatness of the labour."

[101] Ian Maclean ("The Interpretation of Natural Signs: Cardano's *De subtilitate* versus Scaliger's *Exercitationes*," in *Occult and Scientific Mentalities in the Renaissance*, ed. Brian Vickers [Cambridge: Cambridge University Press, 1984], 231–52, at 240) points out that here Cardano has aligned himself with Aristotle and Galen, and also with conservative philological scientists, such as Jean Riolan the Elder (1538–1605, at Paris).

But to return to the subject: although the obscure things are mostly rarefied and the slight ones are elusive,[102] they are not all like that, nor all the time. Things that are obscure and complex more through defective words than through any technical activity,[103] like knots[104] that by chance return into themselves, and also things that appear to the senses as rarefied and not compact—these do not merit the name of subtlety. Of this sort are thin human legs, damaged from the outset by poor nutrition or other mishap.

Therefore subtlety exists in three things: in substances, in accidents, and in representations.[105, 106] Among things of which there is some knowledge, some exist, while others do not, but only appear to exist. Of those that appear, some do so as we slumber, but others while we are awake. Of the latter, some appear via the internal senses, but others via the external senses. The external senses of which an account is required are four: touch, sight, smell, and hearing. Taste seems actually unworthy of notice, so to speak. A fourfold representation is relevant to each of these: either because they do not perceive what they should, as when flesh is painlessly &4 pierced round a needle,[107] or because they perceive what is not there, as in ecstasy and dreams; or perceive features otherwise than they are, like sizes and colours; or not on a similar basis, as in a likeness. Again, under this heading things seem numerous, but are not so. For speech is a representation due to the imaging power of hearing; a picture, a sculpture are representations due to the imaging power of sight; and writing seems to exist through vision and hearing; but both writing and speech exist through the aid of the internal sense.[108]

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[102] "subtilis": I adopt Cass's "elusive" here to translate this word.

[103] "arte."

[104] "nodi."

[105] "Representationes": A difficult word; Cass (141, n. 4) points out that later Cardano promises to discuss 24 kinds of "representationes" in Book XVIII, but in that book does not use the word at all; he has replaced it by "visiones." Julius Caesar Scaliger (1484–1558) was a celebrated Italian scholar who published a notable polemic against Cardano's *De Subtilitate* (*C. Scaligeri Exotericarum Exercitationum liber quintus decimus de Subtilitate, ad H. Cardanum* [1557]; see Introduction). He (8) is critical: he holds that representations comprise "species" and "imagines," and derive from "accidents" (in the philosophical sense).

[106] The material following, up to [A] on 8 (1560), was new in the 1554 edition. The text of what it replaced is available in Nenci's edition, Appendix 1, 109.

[107] On 299–501 (1560) (Book VII) the possibility of this being achieved by magnetism is subjected to experiment.

[108] The syntax is obscure: "Nam oratio, auditus; pictura, sculptura, visus, species imaginantis virtutis; scriptura autem visu et auditu constare videtur; utraque autem, tam scriptura quam oratio, auxilio interioris sensus constant." Cass broadly concurs.

And some existent things are substances, others accidents.[109] Of the substances, some possess bodies; others lack them, and all these are immortal and incorruptible; they have no contrary, and subsist in themselves. Consequently of those that are incorporeal, some are dependent on nothing, but are the causes of other things, and some are dependent on others. There is only one substance that is dependent on nothing: God most good and immeasurable, and the universe itself is His handiwork. His intellect, wisdom, power, and goodness, and then the origin of the universe, will be for description right at the end, being the most perfect of things. But the order[110] of the universe will be for consideration there too, because the universe exists in an arrangement—itself in time, or time in it.

So there will be these seven topics to be covered in the last book.[111][358] And of the entities that are dependent on others and lack a body, some are the causes of other entities, and others are not the causes of anything. And those that are the causes of others are linked also to &5 immortal bodies, so as to be causes permanently, and are called primary substances.[112] There will then be four features to be examined in these: they understand, they produce, they persist (since they appear to exist within time),[113] they move, and they are situated in a body. But a great deal of this sort and belonging to the final discussion has been relegated to the books *De Arcanis Aeternitatis*;[114] the reason is that since all this is beyond the human mind, only the more lucid points and those capable of manifest proof, also general points, were appropriate for this undertaking. Immortal and incorporeal entities that were not the cause of anything were attached to a mortal body. So some of these are manifest, but about others there is uncertainty. And if these are of a more notable sort, some people call them demons, which we will discuss before intelligences.[115] But before that, we will discuss[116]

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[109] On the Aristotelian distinction between substance and accident, see Jonathan Barnes, "Metaphysics," in *Cambridge Companion to Aristotle*, ed. idem (Cambridge: Cambridge University Press, 1995), 66–108, at 77–80.

[110] "ordo."

[111] I cannot identify these in Book XX.

[112] The edition of 1550 has here instead of "primary substances," "intelligences or angels. We employ these names freely, though one has a Greek meaning and the other a Latin one."

[113] "in aevo."

[114] This work is Cardano's own, the *Secrets of Eternity*, and was probably originally composed in 1538–1539 (Maclean, *De libris propriis*, M44, 68–70). But since it was not published in printed form until the *Opera omnia* of 1663, Maclean ("Interpretation of Natural Signs," 236) draws attention to its inaccessibility to the ordinary reader, as a circumstance that avoids "casting pearls before swine."

[115] Cardano discusses demons in Book XIX of the present work, and "Angels or Intelligences" in Book XX; indeed, this was the original title of that Book, but it was altered for 1560.

[116] In Book XVIII.

the so-called twenty-four[117] kinds of representations, because the topic is closely linked; indeed, most people trace marvels to them as causes. However, it is not yet clear to students of nature whether they exist, so let us speak of them as only probable, making a start from effects, and that only with hesitation.

We have spoken elsewhere about the immortality of the intellect and its separation.[118] So it remains for us to speak of its experiences.[119]

But there are practical skills[120] which we will cover before these, and then cover the things that exist through these skills. Before the skills, we need to speak about branches of knowledge and about the intellect, since we have debated about prudence &6 in the books on wisdom.[121] But beforehand we need to speak about the soul[122] and the intellect,[123] since without them there is no knowledge nor acquaintance with principles. And after that, about the subtilities that are of some more trivial kind or of no use,[124] which cannot be related to practical skill, since they contribute nothing to it; nor can they be related to knowledge, not being proved. Furthermore, the soul being linked to a mortal body, senses come into being; and then, as there can be no senses without things that can be sensed as well, pleasure develops for the sense that is perceiving things that can be sensed. Beforehand we will need to speak about three topics: sense, things that can be sensed, and pleasure.[125] Colours, however, we will postpone for convenience's sake till the discussion of illumination.[126]

Of corporeal substances, some are in fact immortal, like heaven; others are liable to corruption. Of the latter, too, some are simple and others mixed. And all these have certain principles, like position and motion, and bodily resistance, and

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[117] The basis of this number is discussed by Nenci, 56 n. 4. It appears to comprise the "fourfold representation" already mentioned of each of four external senses, giving 16, plus four features of substances and four of accidents.

[118] It is not clear where; evidently not in Book XIV of the present work, which is preoccupied with the soul's immortality.

[119] "affectus"; Cass (79) translates by "characteristic aspects." But I feel the word means "what they undergo" and is a technical term for πάθη.

[120] In Book XVII.

[121] Cardano's own work *De sapientia* was published in 1544. See Maclean, *De libris propriis*, M47 for further detail.

[122] In her note at this point (168–69) Cass points out that the word "anima" used here covers for Cardano the meanings: a) life in a general sense; and b) synonymous with "animus," the seat of sensation, or of understanding. It is not independent of body, but is not to be identified with body; and motion, knowledge, sensation, imagination, pleasure and pain are all attributes of the "anima." It also generates and destroys.

[123] Book XIV.

[124] Book XV.

[125] Book XIII.

[126] Book IV.

a fixed amount of substance.[127] In fact a body cannot be dissolved into incorporeal constituents, nor is a vacuum possible. Then too the form is the starting point, and is in common with other bodies whether capable of being created or not. Consequently all these five features, and then matter, will be for discussion in the prime position and the first book. Next, the four elements (four is taken as their number), [128] then heaven, afterwards light, illumination, and colours.[129] Then we must descend to the &7 composite bodies. Some of these are perfect; some are imperfect, and these are to be treated first. They exist through mixture—which will be discussed in the fifth part.[130] Of the perfect bodies and those that are alive, some have life in themselves, and some of these are of watery substance and are called metals, and others are of earthy substance and are called stones.[131]

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[127] Ingo Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate (Munich: Wilhelm Fink Verlag, 2000), chap. 2.1, 53 ff., discusses Cardano's interpretation of Principles, and points out that this section of *De Subtilitate* was inserted in the 1554 edition; if it had not been, his interpretation would be uncertain.

[128] But in Book II Cardano is going to plead for three, arguing against the status of fire as an element. Cass (143–44, n. 17) asserts that while Plato, Aristotle, and others stood for the four elements, as did the alchemists Arnaldus, Raymond Lull, Paracelsus, and Valentine, van Helmont concurred with Cardano. But this is not true of Paracelsus, who like Cardano denied the status of fire as an element, since nowhere in Scripture was the creation of fire mentioned. In his *Anatomie of the World: the First Anniversary* (lines 205–208; published 1611) the English poet John Donne (1572–1631) too refers to this removal of fire as an element:

"And new philosophy calls all in doubt,
The element of fire is quite put out,
The sun is lost, and th' earth, and no man's wit
Can well direct him where to look for it."

I am indebted to Professor John Henry for this reference.

[129] Book IV.

[130] Book V.

[131] Aristotle's account (*Meteorologica*, 3. 6, 378a17–31; Loeb 287) is that exhalation enclosed in the parts of the earth "produces two different kinds of body, being itself twofold just as it is in the upper regions. For there are, we maintain, two exhalations, one vaporous and one smoky; and there are two corresponding kinds of body produced withint the earth, "fossiles" and metals. The dry exhalation by the action of its heat produces all the "fossiles," for example, all kinds of stones that are infusible—realgar, ochre, ruddle, sulphur and all other substances of this kind. Most "fossiles" are coloured dust or stone formed of a similar composition, for instance cinnabar. Metals are the product of the vaporous exhalation, and are all fusible or ductile, for example, iron, gold, copper. These are all produced by the enclosure of the vaporous exhalation, particularly within stones, whose dryness compresses it together and solidifies it, just as dew and frost solidify when they have been separated—only metals are produced before separation has taken place."

As these come into being through generation and corruption and alteration of qualities, the metals will need discussion first, and the change of qualities which the barbarians[132] term alteration.[133] Then the stones.[134] And of the things that derive life from elsewhere, some, such as trees and plants, lack motion, and are to be dealt with in the eighth place;[135] after them, those that possess motion, but are not generated through seed.[136] But this sort of generation will need to be mentioned; similarly in the tenth place[137] the generation which takes place in animals through seed. And these animals are without intellect. There is to be discussion of the body which has achieved the height of perfection (this is the human being), why he was created, and about his form and actions. The twelfth deals with the aspects of him that relate to his body, which are of four kinds: some are shared by animals, some are peculiar to him; some are actions arising from some special nature of his substance; some are &8 attributable to his manifest structure. And besides, there are some accidents,[138] which need discussion, such as heaviness, lightness (these reside in the elements), compactness, loose structure, roughness, smoothness, hardness, softness. And these are present in mixtures; and there are shared[139] features, such as the sheen and transparency on generated things, and the shape on generated things only.[140] Some terms are used only about other things, such as generation, corruption, nutrition, change, growth, attraction, retention, concoction, expulsion. But there is subtlety in all these whose kinds we have listed.

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[132] As Cass points out (148 n. 20), he says that Barbarians inhabit the fringes of uninhabitable regions such as Africa, and are not so called because of being wild, since they are more humane than many Greeks and Italians—nor because their habits are uncultured, since many of their nations are criticised for luxury—nor because of lack of talent, because they usually have plenty—nor because of roughness, since many are as gentle as Germans and Frenchmen—but because they get in a rage before grasping an issue, and after the outburst are hard to soothe . . . just as a running horse is harder to stop than a walking one, Barbarians are hard to recall from anger.

[133] The word "alteratio" is a Latin counterpart or calque of the Greek ἀλλοίωσις which is to Aristotle one of the six kinds of "Motion" or "Change"; his Greek word is the same (κίνησις). They are: generation, destruction, increase, diminution, alteration, change of place (Aristotle, *Categories*, trans. Ackrill [Oxford: Clarendon Press, 1963], chap. 14, 41, 15a13). On the changing of one metal into another, see Book VI, 421 (1560).

[134] "lapides."

[135] Book VIII.

[136] In Book IX Cardano includes lice, nits, and certain mice in this category.

[137] Book X.

[138] In the philosophical sense.

[139] "communia."

[140] Evidently this means that sheen and transparency are common to stones and to (some) living things, but the shape of generated things is a feature transmitted in reproduction.

So since there is this number of topics to be discussed, and cannot be more, I consider I have now amply explained what needs to be proved about them, and in what sequence. [A] Hence no slight usefulness derives from such an effort, but as much as could ever be achieved from any other discussion, whether it relates to just one kind or to more. For in the first place it contributes to the whole acquaintance with nature, and to knowledge of difficult matters, and the uncovering of obscure ones, and it assists to some extent in the interpretation of all books. It teaches the strengths of technical skills, and displays some novel aspects attractive to know, drawn too from what makes a significant contribution to the accumulation of wealth and resources. It distinguishes the truth among ancient weighty uncertainties, for instance in chemistry.[141] It also displays the sensational works of both nature and technical skill. And it recovers ancient practical discoveries which have been forgotten through the &9 passage of time or through wars of great violence. It also teaches how marvels visible to the senses come about, in all cases. Now let us set about the task before us.

That matter[142] exists is shown by the perpetual generation of things themselves, which always happens from something else.[143] For instance, corn from earth and moisture, and animals from seed and blood, or from eggs, and ash from wood; nothing is so tiny as to come into existence out of nothing. Nor is it sufficient for something to be present, since not much ash can arise from a rush [359]or a straw, but from a great oak there never comes a slight amount of ash. And so there is something resident in all generation that is common, which we call the primary matter or the "hyle." When indeed something is generated from something else, if the form passes away (for otherwise the thing would exist and not exist) what remains must be matter, so long as something remains. Corruption shows the same state of affairs: nothing completely perishes in the course of corruption. For instance, an apple rots and turns into worms; and pieces of wood in the course of burning turn into ashes, and through the heat of fire or of the sun, water turns to vapours or steam.[144] The vapour and steam is something; for it chokes a person, and if it is collected, it turns back into drops of water. So it is clear that there is something in nature hidden below the form, which does not come into being through generation nor pass away through corruption; and this is the very thing that we call primary matter, inborn and never to pass away, as it is the primary &10 thing and is what underlies the many forms.

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[141] "chymicis"—would apply equally to alchemy, I suppose.

[142] *hyle*, ὕλη.

[143] On the history of thought on spontaneous generation, see http://penelope.uchicago.edu/Thayer/E/Roman/Texts/secondary/journals/TAPA/51/Spontaneous_Generation*.html (accessed 17 March 2007).

[144] "fumus."

It persists and exists; in fact it exists in virtue of persisting.[145] Therefore matter is in actuality like our description of it; but when prepared by forms, it is a potentiality, as it can assume them.[146] So matter made ready for a form is a potentiality itself, but in actuality. In the same way a fetus, when not yet complete, is an infant in potentiality, but of the sort that a fetus is in actuality, since a thing thus traced in outline is a mixed thing and is as it appears. When it is compared to the form of an infant, it is said to be a potentiality, because if it existed in actuality, it would already be an infant and not a fetus. So primary matter exists in actuality, and, so to speak, in reduced actuality; in comparison with forms, it is a potentiality; for unless it were a potentiality in relation to them, it would never assume them. Nor indeed does a human being come into existence from a stone, because a stone does not possess the potentiality to assume a human being's form. And matter embraced by the form which it supports at the time acquires a more complete actuality, yet not an entirely complete one, because a complete actuality is one totally devoid of potentiality.

Let us say then that a fig tree's matter, considered on its own, is in actuality, but rather slender actuality; but in comparison to the forms of other things, it is a potentiality to them; yet as supporting the particular form of a fig tree, it exists in actuality. But not even primary matter has been stripped of everything; &11 for, as I said, a handful of straw cannot give rise to a handful of iron, because of scarcity of matter, nor conversely can a handful of iron give rise to a handful of straw, because of excess of matter; it follows that primary matter retains a certain quantity, which we call an undefined quantity.[147] In fact it does not trace out definite limits for itself, as below a form there sometimes lurks a larger space to be filled up, and sometimes a smaller one.[148] For if fire is to come into being from earth, it takes up more space; therefore the prior matter which was supporting a lesser quantity has filled up more space upon the alteration of the form.[149] However, it possesses circumscribed limits of largeness and smallness,

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[145] "Manet autem atque est; quod enim manet, est."

[146] On the subsequent development of thought on matter and form, see C. Lüthy and W. R.Newman, "'Matter' and 'Form': By Way of a Preface," *Early Science and Medicine* 2 (1997): 215–26; N. E. Emerton (*The Scientific Reinterpretation of Form* [Ithaca: Cornell University Press, 1984], 36) remarks how "the concept of form made a remarkable comeback in the sixteenth and seventeenth centuries."

[147] Schütze (*Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 63) discusses Cardano's treatment of the quantity assigned to matter.

[148] Nenci (59 n. 8) on this points out here that the concept here underlies the words "rarus" and "densus"—in the simplest terms, "rarus" means little matter in big space, and "densus" is the converse.

[149] Aristotle (*Physica* 4. 9, 217a21–33 and 217b8–12) similarly discusses the change of bulk accompanying conversion from water into air or vice versa, but in terms of change from potentiality into actuality, not in the Platonic language of forms.

within which it occupies undefined boundaries of size, like some Proteus.[150] And since this fixed limitation of amount is inherent in it in actuality, what is there remarkable about primary matter itself, through which size itself is established, existing and subsisting in actuality? Others have put this more obscurely, not just because of the subtlety of the thing itself, but because most people seeking to write about what they have not completely grasped entangle their actual account in discourse not only obscure but even ambiguous. Further, it follows upon the knowledge—indeed the essence—of matter, that when we obstruct the actual approaching forms, the previous form persists. In that way cold water preserves a medium level[151] in those of a sanguine disposition,[152] by blocking the generation of bile. The fact is, that as primary matter &12 must always underlie some form, if a later form is obstructed by skilled action[153] or chance, the earlier form has to remain. So from there the whole procedure of preservation took its origin. Similarly, in transmutations too an equal amount of matter was needed, since more or less cannot be appropriate. On that basis, things that are alike arise more from like things than from unlike things. Again, the distinction between being loose-knit and compact has derived from plentifulness or scantiness of matter—but we shall say more on this further on.[154]

And so, since all there is of matter has existed from the beginning and has filled up this hollow space of the world, and could not be hemmed in, there could not be a vacuum, since if a vacuum grew larger, matter would have to be removed.[155] There were many points too that showed that a vacuum was

[150] Proteus was in Homer's *Odyssey* (4. 385 ff.) a minor sea-god who could take on all sorts of shapes, but when held till he resumed his true shape, would answer questions. The name is now applied to a microorganism which has a similarly variable shape.

[151] "temperantia," presumably of hotness.

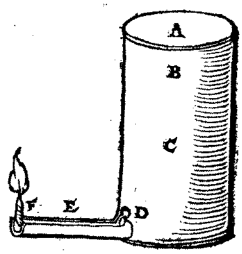
[152] Jean Fernel, a somewhat senior colleague whom Cardano met in Paris in 1552, argued against phrases such as "of a sanguine temperament," pleading that bilious people (a phraseology he did permit) who ejected much bile daily were not necessarily of a bilious temperament and might be fair-skinned, effeminate, and cool to the touch. See Jean Fernel, *Physiologia (1567)*, trans. and annot. by John M. Forrester, *Transactions of the American Philosophical Society* 93 (2003), 3. 11, at 253.

[153] "arte."

[154] On 16–18 (1560).

[155] On this see T. S. Kuhn (*The Copernican Revolution* [Cambridge, MA: Harvard University Press, 1994], 78): "For Aristotle the entire universe was contained within the sphere of the stars . . . at every point outside the sphere there was nothing—no matter, no space, nothing at all (and no vacuums)." And on how vacuums regained credit after the Copernican Revolution, see 89. Also see E. Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge: Cambridge University Press, 1994), chap. 6 ("The Finitude, Shape and Place of the World"), 106–35.

impossible, even though Hero[156] in his *Pneumatica*[157] struggles to show that it exists. But it is not a wise man's job to rebut every absurdity; much less is it part of our plan to pursue with incomprehensible arguments points capable of proof from obvious reasoning. Thus sealed bellows show that a vacuum does not develop—they burst if they are forcibly over-distended. This is because when a space is enlarged and cannot be filled with air (air not allowing so much rarefaction), and a vacuum cannot be produced, the remaining possibility is that the bellows themselves burst. Likewise, to prevent this vacuum,[158] water rises when we suck through a pipe. And it runs &13 down while draining water from the pitcher.[159] These points will be proved below.



On this basis a marvellous lamp has been devised, in the shape of a tower enclosed on all sides, with only the orifice D through which its oil is inserted till the whole is full.[160] It is rigid, made of tin, and when it is

[156] Hero of Alexandria flourished about A.D. 62; this is known because he refers to an eclipse of the moon which can only have been one occurring in that year. This work of his is about devices worked by compressed air, steam, and water; he also wrote upon measurement, mechanics, and mathematics, especially in relation to practical problems.

[157] Nenci (61 n. 10) explains in detail the difficulty of tracing Cardano's actual source here: the only available Latin translation lacked the relevant material, and he may have resorted to an edition of Hero's original Greek, or to manuscripts identified in the note. Hero's view is: "Some assert that there is absolutely no vacuum; others that, while no continuous vacuum is exhibited in nature, it is to be found distributed in minute portions through air, water, fire and all other substances: and this latter opinion, which we will presently demonstrate to be true from sensible phenomena, we adopt." (Woodcroft edition, 1; original text [Schmidt edition] I. 5.) Hero held that artificially a continuous vacuum could be produced; for instance, suction applied to a hollow vessel then enables the vessel to hang from one's lips—this and similar evidence for him shows the presence of a "continuous vacuum."

[158] "vacui necessitate."

[159] The Latin here runs: "Huius igitur vacui necessitate aqua ascendit dum per canalem sugimus; pronaque descendit hauriens situlam ex urceolo." The syntax and meaning are unclear. Cass reads "aquam" for "situlam," her own conjecture, and I have adopted this reading to enable translation to correspond to a siphon, although the anomaly of "water draining (other) water" exists.

[160] Much earlier, Hero (see n. 156 above) too had addressed the problem of making lamps with a constant oil-level; details can be found in A. G. Drachmann, *Ktesibios, Philon and Heron: A Study in Ancient Pneumatics* (Copenhagen: Munksgaard, 1948), 122–25. Cass (162–64 n. 29) points out that Robert Boyle (1627–1691; English natural philosopher and author in 1661 of *The Sceptical Chymist*) in his *A New Lamp* (see Bibliography) in 1681 described an improved lamp; his modification claims to have the following advantages over Cardano's: 1) the air does not get into it by "starts and gluts" as it does in Cardano's lamp; 2) the air in the cavity AF gets warmed up and can drive out oil and

turned round as it is now situated, the oil cannot pour out through D, because if it did, what was in C would go down to D on the basis of its weight and to prevent a vacuum; and what was in B, to C, and what was in A, to B; consequently a vacuum would be left in A. So to prevent a vacuum being left in A, the oil stays where it is, and therefore too the oil in B and C and D. Therefore nothing runs out.

But on what basis then &14 can the oil run out from D through the canal E when oil is being used up after the lighting of the lamp wick at F, and so apparently we are forced to resort again to the vacuum theory? In fact it seems to make no difference, so far as the vacuum theory is concerned, whether the oil is dragged along by the power of heat or descends of itself. However, experience indicates that the lamp does burn, and thus is gradually made empty; but the oil does not run down of itself at all. So the reason is that fire makes the oil more rarefied and thinner by heating it. Growing more rarefied, it swells, and bulges through the orifice D, and its lightest part meantime rises to the top of the lamp, marked A by us. There, being loaded with much air, it fills the space with air, and is thus gradually increased as long as the oil is running out. Great care must therefore be taken to prevent the channel DEF becoming shorter than it should be, or the wick in F larger. Either way, through the excess heat the oil swells too quickly, enough to run out. This is the basis on which the Athenians devised a lamp to burn all year in front of the image of Athena. In that case the space ABCD was enlarged in proportion to the number of days in a year; maybe it would have been more convenient if iron grids had been supported on cork.[161] And therefore the oil, poured out into a very large vessel, will last a whole year if the flame of the wick keeps burning. For the flame to keep burning, the wick should not be consumed. That kind is made from Carpasian linen,[162] as it does not burn; or,

"choak" Cardan's lamp, but in Boyle's there is a double-bottom space into which excess oil can pass; 3) the oil is always at the same distance from the flame, and so the wick is not quickly consumed; 4) the oil can be replenished without moving or extinguishing the lamp. Four years earlier, Robert Hooke had published *Lampas* (see Bibliography), a much longer and more diffuse approach to the same problem, from which Boyle no doubt gleaned something, such as the phrase "starts and gluts," but Hooke is hard to follow in the absence of the illustrations mentioned in his paper.

[161] It is not obvious what this means; Cass (164 n. 31) thinks it means that iron gauze supported by cork was placed under the wick.

[162] This tale Cardano no doubt found from Pausanias, who flourished about A.D. 150; in his *Description of Greece* (I. 26. 6–7; Loeb 1: 137) he writes of a lamp lit at Athens in honour of Athena, which burned day and night for a whole year, because its reservoir held enough oil, and its wick was made of Carpasian linen, "the only kind that resists fire." Carpasus (now Carpas) is the name of the NE corner of Cyprus.

as we will mention later,[163] from threads of encrusted stone.[164] So &15 matter is everywhere, but cannot exist without a form, hence form too must be everywhere. But also a soul, whether because there is to be generation everywhere, or (what more concerns the present account) because in every body there is evidently a principle of motion when it has been displaced from its position. But motion proceeds from nature, not from soul.[165] I do not mind, provided (a point essential to me alone for the present account) you admit that there exists some principle of motion. Indeed, consideration of the soul is needed later, on whether the whole of nature is soul.[166] For the present, since all bodies are mixed or simple, it may suffice that some of these, being light, proceed upward, and others, being heavy,

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[163] At 368 (1560) (Book V).

[164] Both these materials for incombustible wicks are forms of asbestos; Pliny (*Nat. Hist.* 19.19; Loeb 5: 433) wrote, "Also a linen has now been invented that is incombustible. It is called "live" ["vivum"] linen, and I have seen napkins made of it glowing on the hearth at banquets, and burnt more brilliantly clean by the fire than they could be by being washed in water . . . The plant grows in the deserts and sun-scorched regions of India where no rain falls, the haunts of deadly snakes, and it is habituated to living in burning heat." Again (*Nat. Hist.* 36.139; Loeb 10: 113): "Amiantus, which looks like alum, is quite indestructible by fire. It affords protection against all spells, especially those of the Magi." Dioscorides (*De materia medica libri quinque*, ed. Sprengel, 5. 155) also mentions amiantus "good for paper, wicks and cloth, which emerge intact from fire." Strabo (10. 1. 6; Loeb [ed. H. L. Jones, 5: 11]) reported that "in Carystus is produced also the stone which is combed and woven, so that the woven material is made into towels, and when these are soiled, they are thrown into fire and cleansed, just as linens are cleansed by washing." A century or a little more later, Plutarch (*De defectu oraculorum*, 43. 434 A-B) says that napkins, nets, and head-dresses used to be made of Carystian stone, but it was no longer found in his time, except a few threads. Marco Polo encountered asbestos cloth in 1250 (see R. H. Jones, *Asbestos and Asbestic* [London: Crosby Lockwood, 1897], 6–7). Andreas Caesalpinus (*De metallicis libri tres*, 141–42) discusses amianthus which is made into garments that ignite on a fire, but emerge "splendidiora, non deusta"—"more brilliant, and not burnt." Agricola (*De natura fossilium*, trans. M. C. Bandy and J. A. Bandy [New York: Geological Society of America, 1955], 5: 93–94) has a very full account, using also the word "asbestos," and refers to its use in wicks, mentioning many names and wide distribution, e.g. use in India for incombustible clothing of corpses during cremation.

[165] On the history of the changing conceptions of the roles of soul and body and form, see for example J. P. Wright and P. Potter, eds., *Psyche and Soma: Physicians and Metaphysicians on the Mind-Body Problem from Antiquity to Enlightenment* (Oxford: Clarendon Press, 2000), 7–9, and Emily Michael, "Renaissance Theories of Body, Soul, and Mind," in Wright and Potter, *Psyche and Soma*, 147–73, especially 148–58. On the soul and motion see Richard Sorabji, "Body and Soul in Aristotle," in J. Barnes, M. Schofield, and R. Sorabji, eds., *Articles on Aristotle, 4: Psychology and Aesthetics* (London: Duckworth, 1979), 42–64, at 45 n. 8: "For Aristotle, the efficient cause of animal motion was the soul." Also see Book XIV below, at 913 (1560).

[166] On the meaning of "anima" for Cardano, see n. 122 above.

proceed downward.[167] And they are not propelled—they would return violently to their own location. Nor are they dragged—their location is an accident, and does not drag an element itself anywhere—as for instance when water rises. So there is something internal by which an element is moved, or a mixed body is moved by an element.[168] I say, for instance, that a mixed body such as a stone is moved downward by the earth in it, or the water. In fact mixed bodies too are themselves usually moved by the element or elements which predominate in them.[169] And since the bodies themselves have not been of the same kind, they cannot be in the same place, because then the matter would have two forms at the same time. But that it is more and less in relation to the same body is shown by glass eggs—when they are sucked out, they draw water &16 out of a tiny orifice; for the air, becoming more rarefied, is drawn together afresh through attraction and occupies less space than before, and in that fashion it draws water into itself, to prevent the production of a vacuum.[170] So the air itself can be compressed and withdraw into itself, and on the same basis can get more rarefied; and just as there is a limit to rarefaction, which reckons with a vacuum and moves accordingly, so there is a different limit to compaction, and any attempt to override it evokes a motion which is called an impulse. Therefore an impulse arises either when a body sneaks into the space of another, or when one and the same body is so compressed that it cannot tolerate so much compression—then, seeking some other larger place, it prompts the motion of an impulse. Excessive attraction occurs from a vacuum and from excessive rarefaction; in the same way, impulse formation (the contrary of attraction) occurs from too much compactness, or the coalescence of bodies into one. Thus[171] it is established by experience that similar bodies come together and grow rarefied; but the basis is not so clear. Alexander supposes that things have a great potentiality towards diverse forms whose quantities of matter are different.[172] For instance, if air is made from water, the

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[167] For Aristotle, "The nature of a stone, according to the concept of nature in *Physics*, II.1, is an internal cause of its moving down towards an end" (Sorabji, "Body and Soul in Aristotle," 60).

[168] "Intimum igitur est quo movetur elementum, aut ab elemento mistum."

[169] This was maintained by Aristotle (*De caelo* 4. 4. 311a29–b1; Loeb 353): "Bodies will be light or heavy according to the amount of this or that element which they contain."

[170] Hero (Schmidt edition 1, 8–10) argues similarly. But Scaliger (*Exercitatio* 11 [59]) protests that the form of air could not be imagined to emerge from its matter and attract water. He objects to the word "attractio" and prefers "accessio" or "subitio," in this context.

[171] The passage opening here, up to [B] on 17 (1560), was first present in the 1554 edition, and it discusses the scholastic problem of rarefaction and condensation.

[172] Nenci (65 n. 15) cites Alexander of Aphrodisias, *Quaestiones naturales et morales*, 2. 12 (CAG suppl. II, 2, 57, 7–30).

relevant matter gets rarefied, because air needs less matter, as we see clearly in fire coming into being from dust.

But compaction and rarefaction is a partial change of form. Indeed, when air is compressed,[173] it passes over to the nature of water. This is why pieces of wet[174] linen in cupping-glasses &17 compress the air, and so they can do more drawing out. So things that are rarefied or compressed change their form in part. But the form of a body follows the form of an element. So it is intolerable that two bodies should exist in the same place[175]—not because of matter, which is present in a place in potentiality only, and takes up room, and determines a quantity for itself, in fact in potentiality only, not in actuality—but because of the diversity of the forms. Hence a body is capable of compaction, because it has similar parts, but bodies cannot penetrate into each other. Further, in the course of compaction something rather tenuous is seen to be blown away or squeezed out. But if this is so, it will appear that what is rarefied or compacted is being generated. But alteration of the elements is so easy in things that are linked and similar, in order that no genuine generation makes a complete appearance. For instance, in a cauldron air is created out of water through the heat of a fire, but the fire generates nothing. So this is not a generation of elements, but a transmutation into related things. We shall speak of this later.[B]

There will therefore be three natural motions in the universe. First and most powerful is the flight from a vacuum, but more precisely from the form of the element, since it does not tolerate greater rarefaction, nor can the parts of matter ever be separated. So in the case of bellows, when a greater opening-up[176] than the limited air in them can endure, first of all it gets more rarefied; then since the primary matter does not tolerate separation, this air does not undergo more rarefaction, and either it draws something into itself, or it &18 entirely disrupts the bellows. So any motion has usually come into being not from a vacuum, but mostly from the very forms of the air, air that cannot be further drawn apart nor separated. That this is a natural motion is demonstrated by the consensus of

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[173] "cogitur."

[174] "madefacta": this word appears in all editions consulted, including Nenci's. Celsus (*De medicina*, 2. 11) discussed cupping; he used horn cups, from which the air was sucked by the operator's mouth through a small hole then plugged with wax, or else brass cups, in which *burning* (not wet) lint was placed at the start. Presumably it heated the contained air and also perhaps used up some oxygen, so as things cooled down again a partial vacuum was created. Paulus Aegineta (trans. Adams, 2: 326–7) cites Celsus and Oribasius ("who discusses this subject at the greatest length"), neither of them apparently using *wet* lint. I am indebted to Dr Carol Parry at the Royal College of Physicians and Surgeons of Glasgow for the suggestion that the wetting might be with spirit (alcohol) which was then ignited to produce the effect already mentioned.

[175] "Simul," the word here, can in classical Latin mean "at the same location" (*OLD*).

[176] "apertio."

the world[177] on the point, and by the compliance of all bodies, which abandon motions of their own to go along with this one, and the heavy ones rise of their own accord and the light ones descend.[178]

The second motion, as I said,[179] is directly contrary to the previous one; and in a pattern like the first one, it is produced by the vacuum. It seems to be produced to prevent bodies penetrating into each other, but more precisely because of a reason opposed to the previous one: that is, to prevent a form's acquiring more than the right amount of primary matter, just as in the previous case to prevent its acquiring less than the right amount. So this one proceeds from nature, on [361]the same reasoning by which we showed that the previous one is natural— although according to some people it is certainly rather obscure. It is not sufficiently evident either which of these motions is the more powerful. But what is clear is that both motions are much more powerful than all violent motions, and even than the natural motions of the elements; and when account is taken of an impulse or an attraction of this kind, "heavy" and "light" are of practically no concern. On that reasoning, which we will pursue in its proper place, military catapults[180] discharge those iron javelins with such force that no other power could achieve it in propelling anything of the kind. If there were no risk of breaking the machine, nothing could stop propulsion from Germany to India, since the process conforms to the normal pattern of the universe.[181]

&19 The third motion is that of heavy things downwards and of light things to the heavens; obviously everyone admits that this is natural, so I am taking fewer pains over it. And even if it is accepted that there are other motions that we should call natural, provided they always occur in line with these principles, as I have said,[182] nothing will stand in the way of what we had aimed to set forth. There was also a fourth kind of natural motion, in which some things were moved toward others; because it is not general, it will be moved to its proper place, like the so-called Herculean stone,[183] iron, amber, and straw.[184]

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177 "universi."

178 Evidently when sucked up or down.

179 But, as Cass points out (173 n. 41), Cardano has not mentioned it previously in the present work!

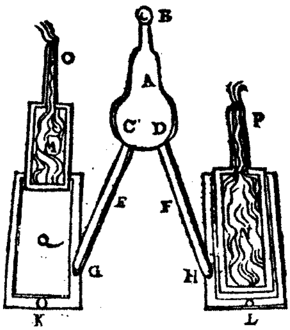
180 Catapults discharged arrows and are described by Vitruvius (X. 10; Loeb 2: 327–31).

181 Philoponus in the sixth century developed his impetus theory of movement: see C. Wildberg in the *Stanford Encyclopedia of Philosophy* (on-line) s.v. John Philoponus.

182 On 18 (1560), just above.

183 The lodestone, more usually named "Heracleus." Its magnetic properties are further discussed in Book VII, at 493–94 (1560).

184 The two latter items are evidently mentioned because they can display properties of attraction on being rubbed. Amber and its behaviour are further discussed in Book V at 370–74 (1560).



Now that these points have been established as principles, the question arises of the basis of the machine of Ctesibius,[185] which is put together in the following way.[186] A is a large bronze &20 cauldron, with a mouth B at the top through which water is to pour out. At its bottom let there be two orifices C and D, above which are valves[187] or pieces of leather placed as in bellows. Let these be raised up from the lower part towards A—but if they are squeezed, let them block these orifices. Let two pipes be fastened on to the cauldron from the orifices C and D, let them be prolonged right and left at E and F, and be inserted into cylinders at G and H. The cylinders are empty, and sunk in water, having orifices K and L in the middle at the bottom; above these are valves with leather as in the cauldron, valves which can be raised upward. When the orifices are compressed, let these shut tightly. In the cylinders are male pistons M and N, polished on a lathe and lubricated with oil, so that they fill the cylinders tightly. Then they are provided with levers and piston rods, so that, as they make their way to and fro, when M rises and the underlying

[185] Ctesibius was an inventor in Alexandria (flourished in 270 B.C.) and, though his own works are lost, records survive of his water-clock (the first accurate one), a war catapult, a water-organ, and a pump with plunger and valve (*OCD* 2nd ed.). Schütze (*Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 136) reviews the descriptions of his machine by other authors of Cardano's time. Drachmann (*Ktesibios, Philon and Heron*, 4–7). describes the variants of this machine in antiquity; it appears that Ctesibius invented the cylinder, the plunger, and the valve, making the first real force-pump, and from antiquity some specimens survive. The machine here is described by Vitruvius (*On Architecture*, Book 10. 7) but Cardano has considerably expanded on his account. It appears both in his margin here and in the French translation of Vitruvius (*Architecture ou Art de bien bastir*, 144–46) as Book 10. 12, because chap. 2 is there subdivided into several chapters. This French translation appeared three years before the first publication of *De Subtilitate*, and conforms only loosely to the text of Vitruvius as now accepted.

[186] In the 1559 and 1580 editions, Latin appears here meaning: "as Ianellus Turrianus of Cremona, a man of great talent in all that concerns machinery, described in his work." Giovanni Torriani (Nenci [68 n. 17]) refers to Gianello Torriano) of Cremona (ca. 1500–1585) was a celebrated clockmaker, who created a wooden robot that could fetch the Emperor's daily bread from the store in 1557. On him see also Maclean, *De libris propriis*, 71 (115).

[187] Cardano uses the form "axis" for a valve here; *OLD* considers that "as" (genitive "assis") is the correct word in the original of Vitruvius.

vessel is emptied, N descends alternately, and fills the cylinder,[188] and expels whatever is contained in it. On this planned scheme, when the male piston M is pulled from O, the space Q of the cylinder empties, whereupon the valve and leather is raised above K, and the water rises until the cylinder is filled on the basis of primary motion.[189] Meantime, when N has been pushed, the piston M can start to be pulled from below by alternating motion and will descend; and[190] the water which was being held in the space Q cannot flow out, with M closing off the contents of the upper cylinder tightly, nor can it descend &21 through K, since the valve presses on the aperture, and the more it is pushed by the weight and impulse by water from the upper position, the more closely it sticks to the aperture K.

The consequence is that water emerges through G, the only exit open, and rising up through the pipe E, by raising the cover it enters the cauldron through the orifice C till the cauldron is full. Later, the impulse from E ceasing, the leather and the valve settles down into C, and the vessel A stays full. But meantime, while M moves down to K, N rises to the top of the cylinder, and the cylinder is filled with water on the same basis. Hence when it is again compressed, it expels water through H into F, and through D on the same basis into the cauldron,[191] which being now full of water which cannot return through C (since the valve and leather stick all the more to the aperture as they are squeezed by the water from above), it follows that on the basis of the second natural motion[192] (through which even heavy things are carried upward) water rising through A into B is poured out, and thus with alternate motion, the cauldron being always full, as much as you like never stops flowing out through B, rising to the top from the bottom at K and L.

The basis is the same in the case of the tube in ships by which ships in danger through water are emptied out. On its pattern was built the device of Bartholomaeo Brambilla,[193] which we saw at Milan, as good as those of antiquity in

[188] The Latin reads "embolum" (piston), but I think this must be Cardano's error for "modiolum" (cylinder), which alone makes mechanical sense here. Cass's translation follows this sense, without comment.

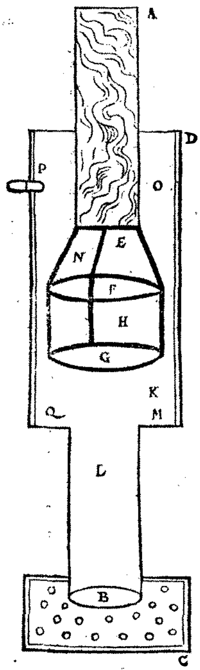
[189] "First and most powerful is the flight from a vacuum, but more precisely from the form of the element, since it does not tolerate greater rarefaction, nor can the parts of matter ever be separated."—in Book I, at 17 (1560).

[190] Ignoring "cùm" for the moment, thus creating a main clause, and taking up its effect in translating "sequitur."

[191] The Latin reads "modiolum" but surely "catinum" (the cauldron) must be meant.

[192] "It seems to be produced to prevent bodies penetrating into each other, but more precisely because of a reason opposed to the previous one: that is, to prevent a form's acquiring more than the right amount of primary matter, just as in the previous case to prevent its acquiring less than the right amount."—in Book I, at 18 (1560).

[193] *Dizionario Biografico* 13: 731–32 lists *Francesco* Brambilla "il vecchio," who was engaged in the construction of the Cathedral at Milan in 1565, but no Bartholomaeus.



its workmanship in every part. &23 BD is a tube, empty inside, made of wood, rounded, fixed in position by rods and levers, wider throughout the upper part DM, and narrower below. At that part it is received in a vessel C, which is immersed in water and has perforated sides all round, so that water can make its way in, but a minimum of gravel and sand, the bottom of the vessel C being solid. Thus it will come about that the tube draws pure water from the vessel when required, but not gravel or sand, which would clog the machine.

At the site M, where the narrower part is linked to the wider one, an upper leather is attached to the part M, and over it leans a thin layer of lead, so that when it is raised above the part Q, it falls down again under its own weight, and closely covers up the channel L. A male piston AE is less in width than the tube, but at the top where D is marked, it is to occlude the orifice of the tube tightly. But OP is to be empty. From the bottom of the piston three solid rods of iron are to protrude, touching the inside of the tube, and you will cover them with leather to stop them touching and scratching the tube. They resemble the pattern of a tripod—wider and more widely separate below (at F) than above (at E). So it is evident that the whole space adjoining N is empty, with nothing but the rods in it; hence there is a clear channel from O and P into N, and conversely from N into O and P—all the [362]space above F is vacant, and there is nothing in it except the piston and the rods. At the bottom of the rods, the circle F is to be &24 set up attached to their extremities, and will not be entirely empty, but in the centre only, and where a channel is being left, with leather above, and above the leather let it be covered with a thin layer of lead, as was mentioned at M, in such a way that when it is covered it stops air passing through, yet the leather with the lead can be elevated towards N and can uncover the aperture itself. And so this will take place if the leather has been attached to the circle by (so to speak) its middle part, holding in the extremities of the rods. But it is free in its remaining part, and is simply blocking the orifice tightly, when it sticks to it.

Further, from the actual extremities of the rods, three more rods are to proceed in a straight line, sticking to the internal walls of the tube. Leather surrounds these from F on all sides above as far as G, adhering closely to the internal walls of the tube, to prevent air actually being able to pass from K into N. Thus it

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To Cass he "seems to be unknown." Nenci (69 n. 18) has traced a remarkable document in the State Archives of Milan comprising a description by Bartholomaeus Brambilla of a novel and more efficient water pump.

will come about that H resembles a cylinder, but one upside down;[194] its bottom is F, and is wrapped round on all sides with leather of a rounded shape, and is open at G. When this has been completed, the piston A will be arranged in such a way that it can move up and down, now descending to M in the bottom part of the inverted cylinder, now being drawn upward to where it is now depicted.

So with things arranged like this, G is to lie above the level MQ, and is to start being raised; then the air contained in the space H gets rarefied and comes to pull Q and raise it. Following upon this, air rises from L into the space K, and following upon it water rises from B into L. But when the piston descends under the impulse of the air and through the heaviness of the lead, &25 at once Q moves down. Consequently the water in L has to stay where it is, because with the closing of the cover MQ, if water were to move down, that limited amount of air would be stressed[195] which would be in the top of L above the water, since the water could not suck up other air from K, because of the cover MQ. But the air which was in K, during its descent through G while raising the cover F, escapes into the space O, and makes its way out through the orifice P. Thus with frequent repetition of the ascent and descent of G and of the piston, the location L is filled up with water; later, on G being elevated again and on the basis of primary motion to stop the air in K undergoing excessive stress,[196] with the raising of the cover QM water enters till the space K gets filled up, and along with it the space H, which is as I said in common with K, because G is the open orifice of the cylinder and not shut off at any point.

So now let it be full, and let the piston descend once more. Then the water in H will raise the cover F and fill the spaces N and O. And when the piston is pulled upwards, the cover in F prevents the water that had ascended into O descending, because in its fall through its own heaviness and that of the water lying upon it, it blocks the orifice. And so it is established that through the agency of this machine water always rises and can never descend. Hence when it has reached P, it is poured out through P (the mouth of the tube) onto the place of your choice, and then with minimal effort you will draw off as much water as you want from B, because with the tube being now full, the motion of the piston A gets easier.[197]

However, the tubes by which ships are pumped dry, as well as fountains and bubbling springs of water, are of simpler construction. &26 The arrangement B and C being maintained, so that stones do not block the machine, the piston has

[194] "Ita fiet ut H modiolum, sed inversum, videatur . . ." — the syntax is unstable but the meaning seems clear.

[195] "convelleretur" — forced rarefaction, in effect.

[196] Again, "convelleretur" — forced rarefaction.

[197] The point of the skirt-like arrangement of leather and rods which passes downwards from the circle at F on which a valve is mounted may be to achieve a better seal between piston and cylinder — like piston rings.

four pieces of leather at the bottom, and the same number at the side.[198] Those that are tied on above are separated by an interval of two cubits or a little more.[199] Their length is a palm's width,[200] and as they are pulled, water enters on the basis of a vacuum; when they descend, they are dilated because of the air's impulse; but also, because of the speed some of the water can make its way upward. And so water rises not only during pulling but also during pushing.

We have already set forth the instance of the state of rest which occurs through the avoiding of a vacuum, but we explained that this should rather be termed the violence of rarefaction, because it happens through the form of an element, an element avoiding greater rarefaction than is appropriate for it. On the same basis we will call it an impulse from compaction, whether it be a motion or a state of rest, like the third motion of an element, whether it is heavy or light. With the lamp as our example, the resting state of the oil at the top has been displayed. And as a second example, the motion of attraction because of rarefaction, and the impulse on account of compaction, is shown in the machine of Ctesibius. Thirdly, there is an instance of both motions, and also of a weighty preternatural resting state. All that remains is for us to show motion from rarefaction alone or from a vacuum, with a fourth example; but the right course is to explain this lower down,[201] with specific reasoning, when we come to demonstrate the motions of the elements.

But now we will deal with motion which happens through compaction alone, of which an example has been evident in military artillery, in which an impelled motion alone makes an appearance. &27 Of just the same sort is the motion that occurs in the

[198] "iuxta"; for this word *OLD* gives "nearby, at one's side, close by, side by side."

[199] Traditionally a cubit was the length of a human forearm, which suggests that this distance is about 60 cm.

[200] On the dimensions of a palm, see n. at 1080 (1560) in Book XVII.

[201] At 34 (1560).

springs[202] of clocks, as it does through the rarefaction in ballistas[203] and scorpions[204] and artillery of the same kind. For when the cord of these is overstretched, so as to contract itself, it moves with a brisker impulse, and propels the stone or arrow placed upon it. And so this principle is reduced to the motion of rarefaction. On the contrary principle, therefore, as I said, the spring in a clock is twisted, because steel is rendered soft and is reduced to a very long thin compact sheet, as you see in the figure. Then it is forced very tightly into a circle, and enclosed in a casing. A thin but fairly strong cord is wound round the casing, and its end is tied to the fairly wide axle of a wheel. Thus it comes about that the steel, under pressure from too much compaction, is tightened, and turns the casing round, which pulls on a rope. Then the axle, rotating gradually, carries with it a wheel which &28 through meshed teeth turns others round.[205]

The sixth instance is the manner in which a state of rest can ensue from an impulse. Of this sort is a jug full of water, but with an empty pipe: when the pipe is turned downward, the water itself seems to be suspended.[206] On a similar basis, stones thrown across water bounce; and a vessel full of water and whirled quickly round does not let the water out—because when the time is insufficient for the splitting of the air, the water stays put, to avoid [363]excessive compression. In the same way, a wide thin sheet of lead floats on water, because during descent the parts in the middle have nowhere to disperse to, and grow too much

[202] "molae"; *OLD* has "millstone or mill," but the context seems to show that it must be the spring, see just below; I have examined Old French dictionaries and the *Dictionarium LatinoGallicum* of Charles Stephanus (1552) without being able to confirm this. However, look at the accompanying Figure in the 1559 and 1580 editions, shown here—it seems to be a clock driven by *weights*, not by a spring! See D. S. Landes, *Revolution in Time* (Cambridge, MA: Belknap Press, 1983), 86: "Spring-driven clocks appeared on the scene towards the beginning of the fifteenth century—about 150 years after the invention of the mechanical clock. The principle was an old one, but well-behaved springs were hard to make." Also see n. 205 below. The 1560 edition, the 1550 edition, and Cass's translation (134) all reproduce a *blank rectangle* as this figure, which is what appears in *Opera omnia* too. Perhaps it became noticeable that the wrong sort of clock had been illustrated.

[203] A ballista could discharge stones and similar missiles, and is described by Vitruvius (10. 11; Loeb 2: 332–39).

[204] A "scorpio" was similar to a "catapulta" and could discharge arrows rapidly at close range (*OLD*). It is described by Vitruvius (10. 10; Loeb 2: 326–31).

[205] The clock spring was a recent invention; about 1500 Peter Henlein, a German locksmith, began to make small clocks driven by springs. The accurate timekeeping available from the isochronism of the pendulum followed a long time after Galileo's discovery of this phenomenon, in about 1582—after the publication of the present work.

[206] I presume the meaning is that if the pipe is reasonably narrow, while it is being turned over and down the water doesn't all run out and get replaced by air. Thus the siphon action gets started.

compressed; or if they disperse beforehand, a vacuum has to be left in the middle. It cannot therefore sink in any way, unless it is first tilted to one side.[207] It has thus been shown that these consequences arise from rarefaction, and how this comes about. And it will be worth our proving that these motions cannot arise from a vacuum on any basis. This will be made plain lower down by detailed arguments. For the moment let it suffice to have expounded enough by some experience of the senses— enough to show the rationale of the instruments. For even if the machines gape with cracks, there is now no fear of a vacuum, yet still they pull, but more weakly and with more difficulty the more they gape. And on this foundation all machines are based that would &29 otherwise rely on some indivisible basis, and for that reason they would all automatically be useless, or at least not continue long. Consequently their usefulness still continues in tasks that are ancient and not precise, but failure is proportionate to the size of the deviation.

Attraction therefore proceeds from the form, which resists passing away as much as it can, in fear of taking on a further rarefaction; we showed previously that on a change of substance and compaction, the form too is altered. But if attraction were to occur through fear of a vacuum, as if with the universe's agreement, this attraction would be infinite. But it is not—in fact it is proportionate to the quantity of the form and of the element and the containing instrument. For a small channel does not drain a moderate amount of water, nor pull a large mass of lead. So this serves to show that this attraction arises from the form, and is proportionate to its powers and magnitude.

There is also a third possible explanation,[208] that planes that do not gape nevertheless come apart. But this could not occur except through the admission of a vacuum. So air is trapped between any planes while they are in close contact,[209] and it prevents the planes from coming apart so far as it can. But since, as I mentioned, it only obstructs in proportion to its strength, it is overcome by a greater effort. You will make this objection only, that this coming apart would be less obstructed by a less amount of air—but it is more obstructed; the more closely flatter surfaces have come together, the less air is caught between them, and yet the more difficult is their separation. The reason is that it is more necessary for that air to depart from its &30 own form, the more rarefied it is. For other substance follows on, as has been mentioned, and a new generating, so that the further it departs from what it was before, the greater the effort to achieve this.

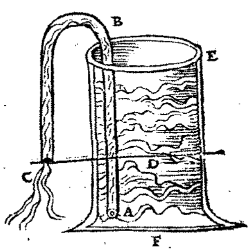
[207] This phenomenon is noted by Aristotle (*De caelo*, 4.6, 313a14–21 and 313b11–21; Loeb 367–69), but his account differs markedly from Cardano's and does not refer to a vacuum nor to tilting. For discussion see Nenci 73 n. 19. The remainder of this paragraph with the four following ones first appear in 1554.

[208] "coniectura," which normally means an inference, conjecture, or guess.

[209] "clauduntur."

But you will say: when air is rarefied, what can be generated except fire? And fire is extremely hot; but between these planes there is no obvious heat — rather, there is cold. But it is not fire, nor hot ether either; this will be made plain later on.[210] For if what is moist is thinned, it passes over not into the nature of fire, but into that of ether; air is moist, and ether is hardly hot at all. Indeed, when other air makes an entry, there is an instant mixture.[211]

Let these examples suffice about these two earlier motions, and then about the state of rest which is derived from them, because it is no part of the present undertaking to discourse about machines, but to do it in the twelfth book of *De Rerum Varietate*.[212] For these let it be enough to have explained exactly as many examples as there are modes of motion too — six examples are enough for six modes. Thus it is manifest that heavy bodies move downward and light ones upward. But some people, dissatisfied with this, add that light bodies desire to be above heavy ones, hence also, air below water, although in its own location, still struggles to get higher up, as is apparent in pitchers when they are turned upside down when half full; and in a bladder full of air which is submerged in water. But this motion is no different from the first one, because water itself, being above, strives to descend, and &31 on its descent the air rises, to avoid excessive constriction. But air in a bladder in a river strives to rise, since the air is in the location of water. Hence one basis for motion in the elements is enough: motion towards their proper place. And it is clear that the water propels the bladder upward, not that the air ascends, because a bladder lying on the ground does not rise.



Here is a problem more worth enquiry: in what fashion does water ascend only so far as it can descend, so long as it is assisted by the motion of rarefaction? This will become clearer with an example. Let there be a vessel full of water, its top being E and its bottom F, and

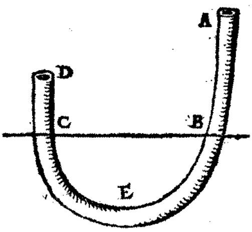
[210] It is discussed briefly in Book II on 80–81 (1560).

[211] Nowadays the term "mixture" implies that the components do not react with each other (the medieval term for this was "appositio"), but this is not the case with a "mistio," which corresponds more closely to the current word "compound." A. Maier in a classic discussion ("Strukture der materiellen Substanz," in eadem, *An der Grenze von Scholastik und Naturwissenschaft* [Rome: Edizioni di storia e letteratura, 1952], 1–141, here 19 n. 20) refers to the distinction here, using the nomenclature of earlier Scholastic discussion of the basis of a "mixtum": "Das mixtum ad sensum entspricht also im Prinzip der physikalischer «Mischung» im modernen Sinn, das mixtum secundum veritatem der chemischen «Verbindung»." "Appositio" corresponds to a "mixtum ad sensum" or modern "mixture"; "mixed temperament" corresponds to a "mixtum ad veritatem" or modern "compound."

[212] This is Cardano's own work, completed in 1553 and first published at Basle in 1557; its twelfth book is entitled *De artificiis subtilioribus* (see Maclean, *De libris propriis*, M104 [94]).

in it is a tube A B C. And let CD be a line parallel to the horizon, along which a &32 plumb line is tautened. Let the channel A B C be filled with water, and let the water be ejected through C; I mean that it will draw up whatever water is above the line C D, and none of it that is below that line, but the full channel will hang down, and the vessel will be seen to be full of water as far as C D. And so a typical example shows that this is the case. Someone might say that this ought to be attributed to the pull of water, but it should not be, since there is no difference whether the vessel is full of water, wine, oil, or milk. So instead a reason needs to be be given for this experience. When, then, the water that rises above C D is exactly as much as what pours out from C, whether the channel is wider or narrower at C than at A, because the whole channel is always completely full, the water that pours out through C is lighter. The reason that the water is lighter in the part above C D than at C is that the water above C D desires to descend, to get below the water lower down in C, and so it compresses that water, and drives it into the channel. But the water below C D does not desire to be at C—because C is above its position, therefore it does not wish to rise. But water that flows out through C does not present a cause to be considered, since it is instead lower than the water actually contained in the vessel. For that attraction is not present unless on a &33 basis of continuity; continuity depends on the basis of rarefaction, none of which can be present with the water now emerging from the mouth of the channel C.

To conclude: all this discussion is resolved by the line of thought [364]that water that is to pull other water along with itself ought to be contained in a vessel, since without that, it cannot be set in motion, but it is assisted by the arrival of air, and approaches equilibrium like a continuous body. When, therefore, the small orifice C is lower, it will reach it, but when it is higher, it will not descend, because what is on a lower position on a vertical line, as at A,[213] will be compelled to rise to C, which is on the vertical line D.



But if water descends to start with and then ascends, as in the figure following, then it will be able to get from A to B, thence to E, and thereafter to C and to D, if D is less far from the line B C than the location A from which it descends. &34 But in individual distances[214] there ought to be a fixed difference in height between A and D. For the longer the path has been, the greater the difference should be between A and D, in accord with the measurement of height. Hence arise the mistakes of some people, who in trying to lead off water on a gradient[215] have suffered enormous losses of their

[213] "quae e directo est loci inferioris, ut in A."
[214] E.g. between A and B.
[215] "ad libramentum."

expenditures. So in each mile,[216] A ought to be higher by a palm width than D—just as in ten miles it should be so by ten palm widths.[217] The cause of this is water's roundness of form,[218] which is apparent also on the surface of pitchers. Hence, granted that A is higher in level than D, it will not be higher sometime or other in the interval between A and D. It also lacks some impetus. But I wanted to add these points now, points as it were beyond my intention, because the risk is great and the mistake frequent.

But now let us proceed to the need to explain by examples the simple motion of elements. Well then, an example of heavy motion is provided by clocks driven by weights, which turn wheels by gradual pulling. And innumerable examples of

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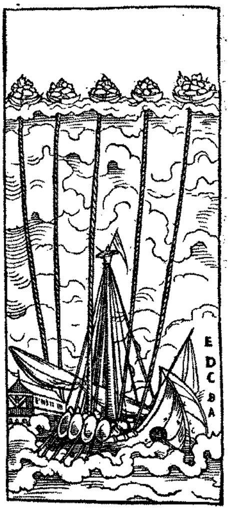
[216] This is presumably an "Italian mile," a measure that enjoyed prolonged currency especially for marine navigation. Estimates of its length vary with the region where they were current; *Enciclopedia Italiana* (Rome, 1934), 23: 246, concurring with *Dizionario Enciclopedico Italiano* (7: 744) supplies the equivalent as 1.460 km but notes marked divergences outside Rome and Genoa and Sicily. And so there were; Horace Doursther, *Dictionnaire universel des poids et mesures anciens et modernes, contenant des tables des monnaies de tous les pays* (Brussels: M. Hayez, 1840), 279, gives the following equivalences: English statute mile, 1.6093 km; "ordinary" Italian mile, 1.8522 km (and this corresponds precisely to the present-day international *nautical* mile agreed in 1928, and is a mere 0.06 percent shorter than the UK "imperial nautical mile," the two thus appearing the most credible present-day representatives of Cardano's "Italian mile."). Doursther offers also: Milan mile, 1.6526 km; Venice mile, 1.7387 km; Naples mile, 1.4895 km; Rome mile, 1.4725 km; Tuscan mile, 1.6535 km. Kelly's *Universal Cambist and Commercial Instructor* (1826) concurs precisely with Doursther where they both offer equivalents.

Encyclopedia Britannica (1966 ed., 33: 488Fc) offers 1.489 km., which closely agrees with the equivalence given by *Chambers Encyclopedia* (1967, 9: 395a) of 13 Italian miles = 12 English miles, or 1 Italian mile = 1.486 km. But these do not appear such credible equivalents for Cardano's "Italian mile."

[217] Adopting 12.7 cm as one palm width (see my note in Book XVII at 1080 [1560]) and a mile as 1.489 km as in n. 216 above, this indicates a slope of about 8.5 cm per km—for open aqueducts. A.T. Hodge (*Roman Aqueducts and Water Supply* [London: Duckworth, 1992], 218) records that the slopes of Roman aqueducts were in general much steeper—1.5–3 m per km—but (190) in the case of the remarkable aqueduct of Nîmes which passes over the Pont du Gard in southern France, the slope was a mere 7 cm per km, a little less than Cardano's recommended minimum figure here. According to Pliny (*Nat. Hist.* 31. 57–58, cited by Nenci here [77 n. 22], the gradient of *piped* water should be at least a quarter of an inch every hundred feet (which corresponds to about 20 cm per km), and if it flows in a tunnel, there must be vents every two hundred feet. Nenci cites a work first published in Rome in 1544 to the effect that a "thumb" in 600 feet would suffice.

[218] the meniscus? Not necessarily so; Archimedes has, in Prop. 2 of his treatise *On Floating Bodies*, 1, that "the surface of any fluid at rest is the surface of a sphere the centre of which is the same as the centre of the earth" (ed. Heath, 173).



this kind would be easily found. But this single example may be offered of light motion. &37 When ships sink in a channel, and there is a plan to pull them up, skiffs laden with rocks are tied to the vessel with ropes by divers, in such a way that the ropes are as taut as possible; then rocks extracted from these skiffs are unloaded into a similar number of empty skiffs, with the result that the skiffs that are emptied out pull the vessel up gradually from the depths along with themselves. For air, refusing to be below water, raises the skiffs (which were almost sinking through the weight of stones) up to the water's surface, hence the vessel is pulled upwards almost in proportion to the relative height of a skiff. Let it be pulled accordingly from A to B; then let skiffs full of stones be tied to it with ropes, and on the transfer of the stones the vessel will be pulled to C. In turn, the previous skiffs into which you have transferred the stones are bound with tight ropes to the vessel lying at C, and they will pull it to D on the removal of the stones, and with continued transfer it will be pulled up in the end to the surface of the water.

But you will say that a great many skiffs will be required to bring up a trireme. That is true, but the principle involved runs as follows: any vessel or skiff can raise as much weight as the weight of water it can contain. For instance, if a trireme can take on in a river a thousand amphorae of water, weighing ten thousand talents,[219] that trireme will convey ten thousand talents on a river.[220] But if the same ship in the sea takes on these same thousand amphorae, weighing twelve &37 thousand talents (for sea water is heavier than river water),[221] it will convey twelve thousand talents in the sea. And on that basis it is clear why we usually refer to vessels by measure— for instance "a ship of a thousand or five hundred amphorae" means the same as if you say, "that can carry a thousand or

[219] In antiquity 25.86 kg was a typical equivalent for a talent weight (*OLD*). An amphora (see Book XIII at 889 [1560]) contained wine weighing 81 pounds, and a Venice pound weighed about 436 grammes; there were wide divergences between different regions, and a Tuscan pound by statute weighed 340 grammes (J. V. Field, *The Invention of Infinity* [Oxford: Oxford University Press, 1997], 65). Thus the contents of one amphora weighed 35.316 kg, but this is not in accord with the ancient value for a talent weight.

[220] Nenci (80 n. 24) points out that Aristotle in *Meteorologica* (2. 3, 359a5–11; Loeb 159) noted the difference and that it might imperil a heavily-laden ship proceeding from the sea into fresh water; Aristotle offered an explanation, and furthermore, he added salt to water and showed that eggs then floated in it, "even when unblown." (He did not quantify the effect.)

[221] But only by two and a half per cent, instead of the twenty per cent mentioned here.

five hundred talents of weight." For the kind of capacity a ship has, as I said, on a basis of water, is the amount of weight it can carry—evidently the size of the weight of water it holds. So from this it is clear that the same ship will carry different weights in different waters, since the weights of the waters themselves too are different. In conformity with this theory, it appears that the size of the weight is proportionate to the water bearing up on it;[222] suppose (if I may offer an instance) that a skiff supports twenty amphorae, this is because the air enclosed in the twenty amphorae of water is impelling it upward, so that the air held in the ship can take its place. So this experience agrees prettily with the theory stated above:[223] that a bladder full of air is propelled upward by water, because the bladder occupies the place of the water. Hence a bladder will support in air a weight proportionate to the weight of water that it can contain —that is, with a weight imposed on the bladder such that the weight itself is all in air, not in water.

&38 But to return to the raising of a ship: a weight that is in water is rendered as much lighter as the water itself has become heavier. Consequently fewer skiffs will be needed than can support the whole weight of a sunk vessel. There are two reasons why ships are pulled up out of heavier waters more easily than out of [365]lighter waters, and thus more easily out of the sea than out of rivers or lakes. One is, that skiffs support more weight in the sea; the other, that the vessel in sea water is less heavy. This is why, since as mentioned a ship becomes heavier on the surface of water (because it is partly in air) than in the deep, care is needed to ensure that the more it is raised by skiffs, more and larger skiffs are attached, in case through neglect of this theory the vessel not only sinks again, but with the additional effort drags all the skiffs into the deep along with it.

Someone[224] will wonder why it is that, when the skiffs at B are unloaded, and those indicated at A are filled up, the ship that was lifted by the empty skiffs at A does not move downwards—when full, they cannot support the weight. The reason is that after the cables of the skiffs A and B have been made equal, then since the vacuum or empty space or air that is held in the skiffs is more powerful than the ship's weight, the empty space of the skiffs B will pull more than the heaviness of the added weight of the skiffs A will lessen. And so on this basis the ship will keep rising, at any rate on the condition that the cables of the full &39 skiffs are as much shorter than those of the empty skiffs as the weight of the stones presses those skiffs down.[225]

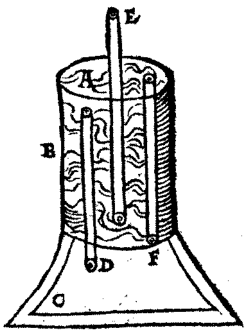
Enough about the simple motion upwards of a light thing; now the topic will be the composite motion made up from the heavy and the light. Hero's machine,

[222] "impellentis aquae."

[223] At end of 31 (1560),

[224] This paragraph first appears in 1554.

[225] Presumably this means that the full skiffs are still exerting a useful upward pull, though much less than that of the empty ones, and since they lie lower in the water, their cables must be shorter to enable their pull to continue.



which we have often discussed, provides a marvellous instance of this.[226] Here is how it is: A is a basin full of water, under which is a vessel B, also full of water, and linked to A so that water cannot pass from one to the other. Under B is another vessel to be named C, empty. A pipe D leads from B into C, and the top of its mouth is to reach almost to the basin. There is another pipe E, which rises clear above the basin, and passing through it, is to penetrate in the middle to the bottom of the first-mentioned vessel,[227] but &40 not be joined to its bottom. Another pipe F has a top orifice situated in the bottom of the basin, and a lower orifice terminating in the actual partition[228] between the two vessels, but in such a way that water from the basin can travel down through the upper orifice into the vessel C.

Then we can observe the water in the vessel B being discharged through the pipe E, and going on doing so till the basin's water is exhausted. What needs showing is how this can go on through two composite motions. Since air cannot exist in C, water descending through the pipe F rises up through the pipe D into the vessel B above. But as there is a space there full of water, water is compelled to rise through the pipe E under the pressure of air, and thus it pours out.

So it is clear that there are two motions here: one is that of water descending from the basin into the vessel C through the pipe F, in accord with nature, the other that of air rising from the vessel C into the vessel B, because (as mentioned) it is impelled upwards by the water. Thus from these two natural motions there is a violent effort through which water rises from the vessel B through a pipe.[229] But when a heavy motion[230] is repeated, it moves bellows or other machines reciprocally, which was appropriately displayed in Ctesibius's machine, and the result

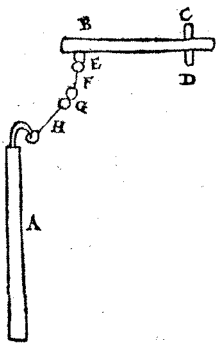
[226] Cass remarks (177 n. 65) that this is a siphon, and is *not* one described in the *Pneumatics* of Hero; I too cannot find it there, and I think the one here is much more elaborate and would not work— see below.

[227] i.e. B.

[228] Cass (106) translates the word "septum" used here as "the enclosed space."

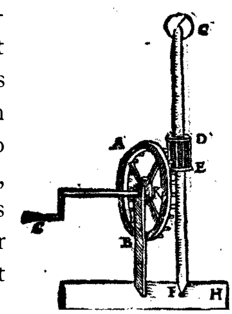
[229] Nenci here cites Hero's *Pneumatica* 1. 37 from the W. Schmidt edition of 1899, vol. 1. But the Latin cited does not seem to relate to the Cardano text here at all— nor does the Greek in Schmidt—it is described as in the translation of Commandino, number 36, pp. 41a-42a. It may be the case that Cardano has invented a sort of siphon device which could not work, and has fathered it on Hero. On this point, note Cass's observation cited above that Hero does not describe this siphon. Although Hero has apparently 8 chapters about siphons, none seems to me to correspond to this. Cardano's account of the action is puzzling because the space C is first of all empty of water, and then "air cannot remain in it," and finally it seems to be full of water. Secondly, water descending from the level of the basin B appears to give rise to water squirting out at the top of pipe E.

[230] "motus gravis."



was the male pistons' ability to rise and descend alternately in the cylinders. This occurs thus: let a wheel with vanes be set beside a downflow of water, as commonly occurs, so that with the unending downward flow of the water onto the vanes, the wheel is rotated; &41 in it there is an axle A, which clearly must itself be carried round too. I omit description of the wheel, as a well-known thing and obvious in every mill. Let a beam B lie upon timbers and be enclosed in rounded orifices, in such a way as to be mobile, and capable of rotating as though in pivots. Beside its end a ring is fixed, to which another is fixed with an iron rod F. This rod again is terminated in a ring, received by another ring G, attached to a rod H. At the end of H a ring &42 is linked, which is attached by a hook on the top of the spindle A, in such a way that it moves with it, but as the spindle returns, the ring too returns to its original location. At another part of the beam two rings C and D are placed on opposite sides of it. Twice two, and three pairs, may be placed in this way on opposite sides.

Then if there is a pair of pistons or bellows, and one is linked to C by a cord and the other to D, on the rotation of the axle first of all the beam is pulled towards D, and then one of the bellows is lifted from C, the other one dropping from D. When the wheel has gone half round the axle, the ring H at the bottom returns to an upper position, and pushes E, because of the rods, and the beam is deflected towards C, and thus the bellows are moved alternately. In fact the right and left of the beam rock in turn, but do not rotate. It is thus possible for many pairs of bellows to move when many rings are placed opposite each other on the beam, but a powerful force of water is needed. It is also possible to link another beam to the same axle on the left, as smiths are used to doing, and thus the number of bellows will be doubled. And no other assistance is required, nor activity other than has been revealed in the single case, but just greater power.[231]



But[232] the transfer of motions usually employed both in mills and in clocks, though well known, depends on a more complex[233] basis. &43 So let there be a

[231] The best guess I can make about the operation of the device described is that the water wheel turns on a vertical axis A, and there is a linkage of rings and rods so that its continuous rotation round a vertical axis is converted to a rocking motion of the beam B. As it seesaws, it first pushes towards C, then towards D, and its rings pull and push alternately on bellows or pistons.

[232] The first seven sentences of this paragraph first appear in 1554.

[233] "subtiliori." On the complexities of clock mechanisms, see Landes, *Revolution in Time*.

wheel AB which can be rotated by [366]another wheel with pegs, as is usual in mills, or by a handle C. And there are teeth on its outer surface facing backward at a cylinder or column FG set up perpendicular to the plane FH. On the plane there stands also a wheel with a fixed pin into which an axle is fastened. And on the column FG there is a toothed pinion[234] DE. And so when the wheel AB turns on the axle CK with a motion from A to B, or from A, upward and downward, the cylinder FG is rotated from DE towards K, or from right to left, hence a transfer of motion occurs, which will be the faster the more teeth of the pinion DE &44 are held by the number of teeth of the wheel AB. Let us use them for the understanding of the Augsburg[235] machine.[236] With these things now covered, now that we have almost finished the discussion of all general motions; the fourth instance in the settling of gradients for water[237] has been clarified; Hero's machine does in the case of the compound motions of elements meet the need for me to attach overall ten examples for the ten kinds—it will be worth gathering them briefly together. We allocated the example of the lamp[238] to absence of motion on account of rarefaction.[239] We allocated the pipe located in the vessel to motion from rarefaction, when we dealt with the descent of water. We allocated the sheet of lead to absence of motion, on account of compactness, also the pieces of leather scattered on water. We allocated the impact of military devices to motion on account of compactness. We allocated what went on in the machine of Ctesibius to a motion of attraction on account of rarefaction, and of repulsion on account of compactness. And the Brambilican machine[240] will be an instance of both sorts of motion, and of absence of motion on account of rarefaction. The motion of a light element produces the recovery of a ship, and that of a heavy simple one, the motion of clocks. That of a heavy but often repeated one produces

[234] "curriculum dentatum." The meaning given here is a guess, not supported by *OLD* nor *L&S* nor Thomas Cooper's *Thesaurus linguae romanae et britannicae* (1584), nor by the *Dictionarium LatinoGallicum*.

[235] This machine is described on 50–52 (1560) below.

[236] From www.deutsches-museum.de/bib/entdeckt/alt_buch/buch0398.htm: "Augsburg besaß bereits im späten Mittelalter eine vorzügliche öffentliche Wasserversorgung. Die Machina Augustana, ein im 16. Jh. beim Unteren Brunnenturm am Mauerberg eingebautes siebenfaches archimedisches Schraubenwerk, war so weithin berühmt, daß Hieronymus Cardanus in seinem erstmals 1554 erschienenen Werk *De subtilitate* darüber berichtete." Thus Augsburg had a sevenfold Archimedean screw device for its water supply in the 16th century, on which Cardano comments in the present work. It was located between the "Brunnenturm" and the Mauerberg, the latter street being still in existence. I am indebted to Mr Peter Milne of the Map Library of the National Library of Scotland for assistance in locating it.

[237] "in libramento aquarum."

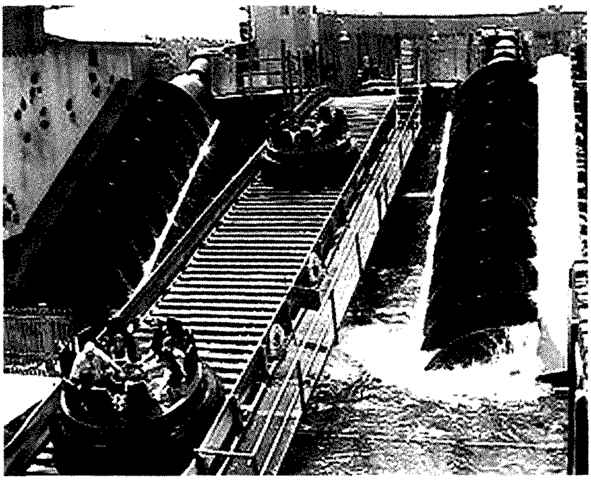
[238] Described on 13–14 (1560) above.

[239] "raritas."

[240] See n. 193 above on Francesco Brambilla.

the alternate pumping[241] of bellows. That of heavy and light operating together to one purpose produces Hero's machine.

So[242] with that this account could appear complete; but we have not covered all kinds: these ten patterns[243] fall within two kinds. &45 One kind has only one motive power,[244] like Hero's machine; the other has two differing motive powers,[245] like the Brambilican one. Then there remains a third kind, which comprises machines that have several motive powers, but not differing ones. That does appear the most notable kind, because it approximates more to the principal or independent[246] motion. This motion comes into play when water, for instance, has turned the wheel by which water is poured out.



Of this sort, the first is the invention of Archimedes[247] called the screw, of which Diodorus Siculus[248] gives an account twice in his ancient history, saying that Egypt was dried up thanks to the screw invented by Archi-

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[241] "iactatio."

[242] The material up to [C] on 55 end (1560) in the translation here first appeared in the 1554 edition.

[243] "exempla."

[244] "motor"—in this case, compactness.

[245] Compactness and rarefaction.

[246] "αὐτοκινέτῳ," "self-moving." The orthodox spelling is αὐτοκινήτῳ.

[247] Mathematician and inventor (c. 287–212 B.C.) at Syracuse, of very great distinction. For details see *Dictionary of Scientific Biography* (hereafter *DSB*), 1: 213–31.

[248] Diodorus Siculus (Greek historian, flourished about 60 B.C.) in his *Bibliotheca Historica* (5. 37. 3–4; Loeb 3) wrote that in the mines in Attica, the workers "draw out the waters of the streams they encounter by means of what is called by men the Egyptian screw, which was invented by Archimedes of Syracuse at the time of his visit to Egypt; and by the use of such screws they carry the water in successive lifts as far as the entrance, drying up in this way the spot where they are digging and making it well suited to the furtherance of their operations. Since this machine is an exceptionally ingenious device, an enormous amount of water is thrown out, to one's astonishment, by means of a trifling amount of labour, and all the water from such rivers is brought up easily from the depths and poured out upon the surface."

medes.[249] If this is so, then since Archimedes flourished at the time of the second Punic War, I do not know how Egypt could properly have been inhabited in antiquity.[250] But whatever the truth, this is undoubtedly a notable instrument, and worthy of such a craftsman. Vitruvius recalls it at the end of his work.[251] But Galeaz de Rubeis, our fellow-citizen and a worker in iron, whom we are going to mention later,[252] thinking he himself was the first to discover the screw that

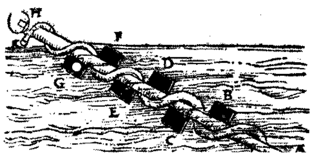
[249] This device is still in use today, because of its remarkable ability to pump water containing much solid matter without clogging or jamming. See J. P. Oleson, *Greek and Roman Mechanical Water-lifting Devices: The History of a Technology* (Toronto: University of Toronto Press, 1984), 10 and 291–301. He notes that the device had remained in widespread use ever since antiquity, but was not well known in northern Italy, nor mentioned by Agricola (on whom Cardano draws very extensively)—which is why Galeaz de Rubeis, Cardano's acquaintance, re-invented it and as mentioned just below, "went mad with joy." See also on these screws Hodge, *Roman Aqueducts and Water Supply*, 248–49; he points out that they were costly in terms of labour, and that what irrigated Egypt was the flooding of the Nile rather than mechanical devices, which indeed are not even mentioned by ancient agronomists (Varro, Columella, Cato). J. G. Landels (*Engineering in the Ancient World* [London: Chatto and Windus, 1978], 59–63) also gives helpful detail on these pumps. On just how they work, see the excellent engineer's account by H. Addison ("Experiments on an Archimedean Screw," in *Institution of Civil Engineers: Selected Engineering Papers* [London: Institution of Civil Engineers, 1930], no. 75).

[250] *i.e.* before the time of Archimedes.

[251] In his *De Architectura* (10. 6, Loeb 307–11); it is not attributed to Archimedes there. Vitruvius contributes admirable practical details upon the construction of a water-raising screw with the materials then available, and mentions too the appropriate tilt for the screw, quoting the familiar right-angled triangle with sides 3, 4, and 5; 3 being the vertical one, this means that the screw is to be tilted up out of the water at an angle of about 37°. In fact, however (see Addison, "Experiments on an Archimedean Screw"), the optimum angle depends on a number of factors such as the pitch of the screw. On Vitruvius see *OCD*.

[252] On Galeaz de Rubeis see Book VI, 432 (1560)—very briefly. But Cardano mentioned this man elsewhere, as Cass points out (178 n. 82); in his *De Vita propria* (cap. III, *OO* I. 2b) he wrote that Galeazzo del Rosso was a family friend of Cardano's father, predeceased him, and greatly impressed the youthful Girolamo Cardano: "Vtebatur amico vnico et familiari, sed satis disparibus studiis Galeazio Rubro (familiae hoc nomen erat) qui illi praemortuus est . . . is enim est qui Archimedis cochleam inuenit nondum vulgatis Archimedis libris: Gladios qui plumbi instar flecterentur, et ferrum penè vt lignum scinderent: et quod maius fuit, thoraces ferreos (me spectante saepius experimentum, eram autem adulescentulus) qui ictibus igneorum tormentorum militum legionariorum resisterent; adeò vt quintuplici ictui, vnus idem suffecerit: vixque rimulam contraxit." So Galeazzo was "the man who discovered the Archimedean screw before the works of Archimedes had been published, swords that could bend like lead [the outcome surely of incompetent ferrous metal technology!], and iron that could cleave wood; and what is more, iron breastplates (I often saw them tried out when I was young) that could stand

had been invented long before, went mad with joy. We have seen him rotating a grinder,[253] and a little later driven out of his mind.[254]



The machine was like this. &46 A solid piece of wood AH, straight, rounded, uniform, and so long that when at an angle to the water's surface and fixed in a trough, it sticks out above the water as far as required, is to be wound round with a simple metal channel fashioned to the pattern of a screw. Some people use a multiple one; three appear to me necessary, channels rising so gradually that all the intervals are taken up. A channel has two apertures: a lower wider one and an upper narrower one. Let the latter[255] be called K. Then it is required to show that where the piece of wood is confined at its ends A and H, in such a way that it can be rotated, it will be rotated by the water's motion. Secondly, that when it is rotated, the water will rise and be discharged through K. For the added fins BCDEFG, encountering the water either between the spaces on each side or at the junctions of the wood &47 with the channel, will have to turn that instrument,[256] because they can increase in length and width. But the weight AH is small, and has even got much less because of the tilt and the axles being placed in rings so as to be capable of rotation. This is also shown by the mills on the rivers Po and Ticino; there, though the waters flow very gently, by this clever device millstones rotate to crush and grind wheat.

But it is evident that the water itself rises from L to K, because when L is raised, the following part becomes lower, and so the water will move down, and this principle always shows that the water makes towards K. This corresponds very beautifully to experience, and we have tested it more than once.

So when the axle or piece of wood has turned in the female bearings A and H in which it is pushed till the channel has got full of water, it will be poured out through K over the level of the bank. Hence this theory does not appear conclusive; water perpetually moves down, and so will end in a lower position than at first. Yet nevertheless it does not always move down, but the part that does so is greater, and impels the lesser part and makes it rise. But when it has started to pour out, then the machine will rotate more readily, and the water will run out of itself, so to speak, because of what we have shown about the descent of the water.

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up to the fiery artillery of legionaries, so that a single one could resist a five-fold blow and hardly suffer a crack."

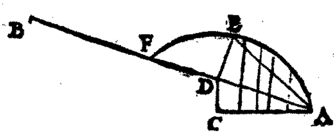
[253] *OLD* gives for "trusatilis" a non-rotatory type of grinder, but an Archimedean screw might perhaps be meant.

[254] "mente excussum"; this phrase is not classical in *OLD* or *L&S*.

[255] "illud" clearly must here indicate "the latter," though conventionally it means "the former," since K is marked at the top in the figure. However, Cass writes "the former."

[256] The screw.

There are some people who fasten &48 plates to the channel, and link everything together, to make the machine get sturdier and stronger, and they put pegs into the plates, not into the piece of wood, for greater convenience. But anyone will be right to wonder why, when the part of the channel next B is rising, and both L and C are moving down, the water does not run back into L and be poured out again (as L is lower than C) and from the same place. The reason for this is twofold: first, because the water in B is propelled by the [367]water in L, and so passes across to C and does not return; the other reason is a geometric one, which shows that a middle zone between L and B is higher in the revolution than is the middle part between B and C. Further evidence is the fact that a lead shot[257] placed on it, though not pushed by anything else, nevertheless rises to K.[258] And the proof is this: let there be a piece of wood AB, in the plane AC; let the elevation of the part AD of the piece be DC. Let the part of the screw corresponding to that part be AE, and its altitude DE, for example, be half as much again as DC, and let a straight line AE be drawn; then all the lines between AD and AC will be less than the lines established directly between AD and AE, from the proofs in the sixth book of Euclid's *Elements*.[259]



&49 Then let AB be rotated, in such a way that when E is in the lowest position, a rounded weight placed at A will be in line with D. Then because DE is longer than DC, if E is in the opposite of its previous position, it will be below C. But C is in line[260] with A, so the weight will be lower than it was at first. But all the lines preserve the same relationship, and are even longer on the circumference AE than on the straight line AE, measured from the line AD, because a

[257] "sphaerula."

[258] A lead shot, being spherical, can roll; and just as the water is carried upward in pockets of continuously changing shape created by the three-dimensional geometry of the rotating screw and its casing, a lead shot can roll upwards as the screw rotates. So does any solid material suspended in the water being pumped upward.

[259] But I cannot locate such proofs in the sixth book, nor does Nenci cite any. Cass, however (178 n. 84), refers to VI. 4, and writes, "For the continuations of the lines perpendicular to AC (see the figure) between AD and the arc AE are equal to or longer than their segments within the triangle ADE; these in turn are longer than the lines in the triangle ADE drawn from their intersection on AD perpendicular to AD and thus parallel to DE; and each of the latter is longer than the continuous line in the triangle ACD perpendicular to AC, since these lines form triangles with a side in common on AD which, being equiangular with the triangles ADE and ACD respectively, have sides in proportion." I am so far unable to follow this, and it occurs to me that in the Figure, at ACD one may be looking at an (imaginary) plane surface, but at AEF one may be looking at the complex three-dimensional helicoidal surface of the screw.

[260] "e directo"—sometimes means "on a *vertical* line" (see quotation from Nemorarius below in note)—but Cass says "horizontal" and is probably right.

part is less than the whole. Thus when AB is rotated, the weight will move down into AE.

But every heavy thing when free to move moves down, so the weight will reach to E. But when it gets to E, as it has moved round it will move down towards F, not towards A, both because of its impetus and because the part between A and E rises, since it had moved down during the previous motion. And the part EF is still on its way down, so the weight will pass from A[261] to F, and consequently from A to B, through many revolutions made on the same principle. This may seem extremely difficult to you,[262] but you can try it out by tying a shoelace round a reed.

But to return to the point. The screw that Vitruvius[263] describes needs some other assistance,[264] but our one turns itself round, the more easily because the coils of the channel will have been closer to each other, and the machine will rise more gently. The more easily it goes round, the more slowly,[265] as is almost the rule &50 in all machinery. Thus contrariwise it will transport the water quickly, but be harder to turn. Furthermore, the difficulty brings it about that the machines get more worn, and we need a lot of water and effort. But we will select speed along with difficulty, where there is a torrent and the height of its banks is excessive. For if the upward slope of the device has been made gentle, the device will be very heavy because of its length. The same principle applies in relation to size, great or small; a small one turns easily but irrigates only slowly. Its application is where a limited amount of land needs irrigation, and the river is deep and runs slowly, and the banks are rather high. In the opposite situations we will use large machines.

There is another sort of machine, at Augsburg as I understand it;[266] however it is included under this type. A column AB capable of rotation is turned

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[261] 1560 reads H, but no H appears in the figure, and 1550 and 1554 read A.

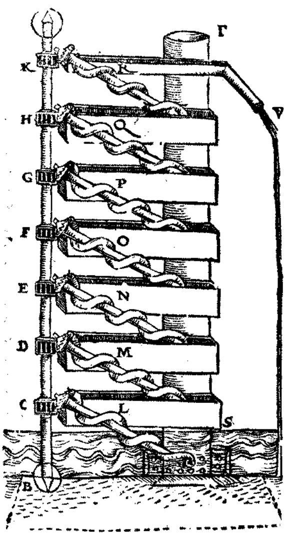
[262] It does; but the elegant diagrams in Addison's paper permit visualising that as the screw turns, water runs first down to form a scoopful of complex shape limited by the screw and its surrounding cylinder, and then each scoopful ascends, changing its shape continuously as it goes—provided the screw is tilted modestly upward (i.e. less than 45°, but this depends on the pitch of the screw). The number of scoopfuls picked up during a 360° rotation of the screw depends on how many helices are installed on the screw; there can easily be two, one ascending all the time behind the other. A separate problem may be that this is intended as a *self-rotating* screw when located in flowing water. The Augsburg device (see 44 [1560] above, also just below) is rotated by a separate little water wheel, shown in its diagram.

[263] See n. 251 above.

[264] E.g. slaves to turn it.

[265] This might be clearer the other way round.

[266] See 44 (1560) above; in Braun's *Civitates Orbis Terrarum* (published about 1600 or earlier) there is in Liber 1 of volume 5 (of 6 volumes) at item 39 a fine picture of Augsburg, its walls and surrounding channels, and the Mauerberg (a street) can be identified



round by a river, by means of a wheel with pegs, in accord with the principle we stated above when we were discussing the transfer of motions. On it there are pinions,[267] for instance, CDEFGHK, according to the number of screws, and screws according to the number of reservoirs, and reservoirs according to the height; the reservoirs LMNOPQR are attached to the column ST. When AB is rotated, all the screws are rotated on the pinions, and the lowest screw C draws up water from the river beneath and transfers it into the reservoir L, &52 from which the screw D draws it up, transferring the water into the reservoir M, and thus with one motion of the column AB, C pours water into L, D into M, E into N, F into O, G into P, H into Q, K into R, drawing it up from the reservoirs beneath. R transfers water through the opening V into the chosen destination.[268]

Once more a problem arises: the screws should not pass on water, as their upper opening keeps ascending. This is why we made the first example a triple one. But they seem to pour out jerkily while they are rising—because as has been shown, there are parts that are moving down, and the whole of the water is moving down. The outcome is that it is compressed and leaps forth, but not as happens at the descending opening of the screw; with several screws situated around the same axis, there is an outflow of waters that is not only continuous[269] but even.[270] Let this be the account of machines in relation to their primary kinds and varieties.

But after we have discussed natural motions that occur in a place, it is proper to learn what "place" means. For the supposition[271] is that this is the fifth principle of natural things, and these suppositions are reinforced by evidence from the

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with the help of a present-day plan of Augsburg, but there is no clear depiction of the device here mentioned.

267 "Curriculi"; see n. 234 above.

268 It is of interest that this device pumps the water up by instalments instead of using one long upward slope. As already mentioned, the slope cannot exceed 45° and may usefully be much less. So if the water has to make overall a steeper ascent, it must do it like a road making its way up a cliff with hairpin bends. Further, the length of each single screw would no doubt be restricted by the materials available.

269 "continua."

270 "aequalis"; I take it that a continuous outflow could be jerky but with some always flowing.

271 "suppositum."

senses.[272] The question then is, "What is a place?" Place is the outermost surface of a body, surrounding the body within it.[273] This surface persists on the removal of the body, because it is related to the revolution of heaven.[274] &53 So it is clear that any place is precisely equal to the body contained by it, and that every body is in a place, and in every place there is some body. For every body has its own outermost surface, and the surface where there is no other body by which as the final body it may be contained—heaven is its space; and other [368]bodies are contained by some other body.[275]

But on the same reasoning, there cannot be a place without a body, if every place is the ultimate surface containing a body. There is also an eternal place, because the outermost surface of the heavenly sphere is unmoving, as being body, it contains both itself and the universe.[276] So place, being in the universe, is eternal and immovable and unchangeable. But as the surface of a specific body, it is altered with the alterations of bodies, and does not persist.[277]

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[272] On the Principles of natural things, see n. 127 above. Note that in Book I, there were originally six principles, but here Place has become the fifth and last. On the changing list of Principles as Cardano proceeds, see Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 54–55.

[273] "locus" (τόπος) is defined by Aristotle (*Physica* 4. 4, 212a2–7) thus in the Loeb translation: "If then a thing's place is no one of these three—neither its form, nor its matter, nor a dimensional entity distinct from the dimensions of the entering or vacating body—it must needs be the fourth of the alternatives, namely, the limiting surface of the body continent [*i.e.* "contained"]—the content being a material substance susceptible of movement by transference." Scaliger (*Exotericarum exercitationum liber quintus decimus,* 15–16) objects to this definition of "place," preferring "id quod intra eam superficiem continetur"—what is contained within this surface.

[274] "ad coeli ambitum comparata."

[275] "Nam omne corpus suam habet extremam superficiem, et illa ubi nullum aliud sit corpus a quo contineatur ut ultimum, coelum est ei locus; alia autem corpora ab alio continentur." Three centuries before Cardano, the question of a vacuum beyond the cosmos was hotly debated: was there one, and was one compatible with sound Christian theology?—the Bishop of Paris in his condemnations of 1277 constrained Paris scholastics to accept that God could move the cosmos rectilinearly if he wished —and where was God, and where was the cosmos created? See E. Grant, *Much Ado About Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution* (Cambridge: Cambridge University Press, 1981), 103–4, and later.

[276] "Est etiam locus ipse aeternus, quia orbis coelestis superficies extrema immota est ut corpus ipsum continet atque universum."

[277] Aristotle (*Physica* 4. 4, 212a14–24) addresses this issue by discussing the situation of a boat in a river, which keeps changing, and for him the water is to be regarded as a "vessel-continent" (a vessel containing the boat) rather than as a "place-continent." Nenci cites also *De caelo*, 1. 9, 279a11–18, Loeb 91, which runs: "This world is one, solitary and complete. It is clear in addition that there is neither place nor void nor time beyond the heaven; for (a) in all place there is a possibility of the presence of body, (b) void is defined

So the place where Alexander sat in Babylonia or Susa is still there, but then it was in the air, in the city and a house, but now perhaps it is in a field, and even underground. And where Cicero, that most eloquent of orators, delivered his peroration at the Rostra,[278] the place remains, and then it was in the air close to the earth, but now perhaps with the expansion of the earth it is underground. Also, in any place there will be, and previously were, an unlimited number of people (time's vicissitudes bringing this about), if Aristotle's view about the eternity of the world is true.[279]

So with us three things are &54 always eternal: mind, matter, and place. But to change mind or matter is impossible. Place can change, and another be adopted. So wherever we have reached on our journey, we are on the way to eternity. And now, the place in which I am writing is eternal, and in it there were perhaps a number of kings or wise men. There are five principles of natural things: matter or "hyle," form, soul, place, motion; time is not a principle, but follows upon motion.[280] But it appears to be close to a principle, because nothing happens without it—we shall say more about this later.[281] Rest too is not a principle, but the lack of one—as are death, cold, dryness.[282] Again, the resistance of bodies, and the vacuum or void, are not principles, since we have shown[283] that these entities depend upon the form, and will show this elsewhere too.[284] Hence

as that which, although at present not containing body, can contain it, (c) time is the number of motion, and without natural body there cannot be motion. It is obvious then that there is neither place nor void nor time outside the heaven, since it has been demonstrated that there neither is nor can be body there."

[278] At Rome this was the platform from which speakers addressed the people.

[279] *Meteorologica*, 1. 14, 352b18 (Loeb 117): "as the universe is permanent."; 353a16 (Loeb 119): "since the universe is eternal." On Aristotle and the eternity of the world, see Grant, *Planets, Stars and Orbs*, chap. 4, 63–82.

[280] Cass cites Aristotle, *Metaphysica*, 12.4, 1070b (Loeb 2: 133–35), that in a sense there are three causes or beginnings: form, privation, and matter; and in a[nother] sense four: form, privation, matter, and motion. And in the Aristotelian treatises of Albertus Magnus, there are three: matter, form, and "principium efficiens."

[281] Cass cites "Cardano 3. 651b"—this is correct and is in Book XVIII of the present work, at 1184–5 (1560), where Cardano reflects on time and especially in relation to sleep and dreams: "But what is time ?—though nothing of it ever exists, yet everything exists in it, and it is always along with everyone ["omnibus assistit"]. It too generates everything and kills off everything—responsible for life and death . . . So we grasp not time [itself], but what is in it and is done and continues."

[282] Aristotle (*Physica* 5. 6, 229b23–231a17) discusses in detail the sense in which rest differs from movement, but not in terms of principles, and does not there refer to death, cold, or dryness. Nenci notes that Book II of the present work (*De subtilitate*) contains more about dryness as privation of humidity.

[283] See 17–18 (1560).

[284] See 55 (1560).

none of these principles is not eternal and primary in respect of its kind[285]—otherwise they could not be principles. But of themselves mind, matter, and place are eternal. Form and motion are in part eternal things among heavenly things, and in part mortal things among what is established below the Moon's heaven. But the soul is eternal in the part by which it has understanding—the rest is mortal. Mind, motion, and place are devoid of body. But mind is totally free of body—motion does not exist without body. And soul, matter, and form are &55 necessarily associated with body. Soul, however, is not regarded as a part of it. And that there cannot be additional principles is proved thus: of existing things, some are alive, some not. All are controlled[286] and come into being, then they persist. So a body stays in its place. They come into being from matter and form. But they are controlled by the soul, which in the more noble beings is mind, and separate from the body; in bodies it is the principle of life.

But the cause through which they persist is the cause of motion, as also of generation, and of the rest.[287] Since all these are motions, both their coming into being and their persistence, so motion is a principle. Let it suffice so far to have made these points about principles in relation to the senses, and so far as concerned this account; indeed, privation is not a principle in this fashion.

What remains for us to make clear is that a vacuum does not occur, a point we are now showing more carefully in addition to the three reasons produced above, drawn from the senses. On comparable reasoning, too, there will be shown what we hypothesised previously about the resistance of bodies; we said, in fact, that two bodies cannot exist in the same place, nor one body in two places, nor can there be a place without a body.

Now then, with this final point proved once more, the remaining ones will become clear too. For in this book the intention is not to prove individual issues, but to handle things under headings.[288] [C] First of all, then, there is no vacuum, so &56 how can what does not exist bring anything about? Next, if it is assumed to exist, a vacuum is not a substance, nor does it proceed from a substance, and to clear up the issue in a word, it is nothing, and so cannot have any action.[289]

Someone will perhaps say that nature stimulates a motion through fear of a vacuum, or so as to avoid one.[290] But that will not do; for since air is more rarefied

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[285] "genus."

[286] "reguntur."

[287] "Sed causa qua manent est motus, item generationis, et reliquorum."

[288] The text of material present at this point in the 1550 and 1554 editions but removed for the 1560 edition can be found in Nenci's edition, Appendix 2 (109).

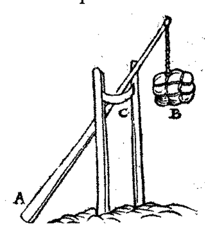
[289] "operatio."

[290] Cardano does not use here the phrase (deriving from both Aristotelian and Galenic precepts) "Natura abhorret vacuum," but François Rabelais (1483–1553), rather senior to him, includes it in Book 1 chap. 5 of his *Gargantua and Pantagruel* (1532), facetiously using this evidently widely recognised phrase in order to encourage imbibing.

than water, at the start before there is attraction on account of a vacuum, when water is rising on the heels of water,[291] the water present previously should be turned into air, and the air in turn into fire, which is more rarefied than air; next the fire should be thinned out itself, and finally this attraction should take place. But we see that water is not turned into air, but exerts a pull, and air does so similarly before it passes over into fire. So since so many intermediaries are still present, it is not through fear of a vacuum, but through fear of rarefaction that nature exerts the attraction which people say is exerted by a vacuum. Nor may I call it violent, with Averroes, because it is entirely natural, like the motions of water when it has been in air and moves downward.[292] It is in fact brought to rest by violence, and thus gets moved naturally. In this way an element which exerts a pull through rarefaction undergoes violence, from which it delivers itself by that motion. But that a heavy thing is pulled upward by that motion occurs by chance,[293] and for what is pulled it is sometimes violent, and sometimes &57 not, as if something light were being pulled upward. It is sufficient that the motion brought about by the principle itself is natural.

But can it happen if what is moved[294] is unwilling or at least not collaborating?[295] Further, what is moved to a place is moved voluntarily, as an element or a mixed thing is, not as a heavy or light thing is. What is moved in this way with the consent of something else actually forgets its own nature. Similarly, someone who urges his son to risk his life when the town's walls are assailed by the enemy is following a sense of duty;[296] if he were not animated by the common interest, he would be reckoned cruel to do so.

But now let us proceed to the motions of heavy things. This motion is free, or it takes place with a weight attached, as in scales or a steelyard. The usual question



is: why are weights set in motion more by weights?—let a weight B be set in motion upon the fork C by the handle A. It is accepted that if a weight (for instance lead, up to a certain measure) is added to the handle, it is easier for it to go down from the sides to the middle with the aid of the weight; but on the other hand, it is moved with more difficulty from the middle to the sides.[297] This is why some limit

[291] "aquae consecutione

[292] Cass cites Averroes 5. 268D, with the caption there: "Motus, qui fit ex necessitate vacui, non est naturalis, sed violentus."

[293] "casu."

[294] "passo."

[295] "non iuvante."

[296] "pietatem."

[297] This is perhaps to be understood with the aid of the circle figure following soon after; the circle is used as a model for the behaviour of a balance. When the handle is aligned far from the horizontal, its end lies in a vertical plane close to "the middle," but

of weight should be adopted, up to which the ease of movement is increased. But if you exceed this, the motion gets harder. This is why people add quite heavy hilts to swords, to make the swords seem lighter and easier to handle. But here too there is a limit to observe.

[369] &58 We have made this addition because most devices suitable for the drawing up of water are operated by the strength of human beings or of beasts of burden. However, even if the machines are set in motion by the rapid impact

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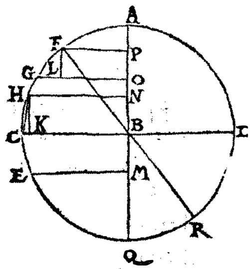
when it is horizontal, its end is at one of "the sides." Cardano is then saying that it is easier to raise the weight B by pushing the handle down from a horizontal alignment, aided by the presence of some lead at A to help, than if the handle is far from horizontal. Cass essentially concurs; she also refers to Pseudo-Aristotle, *Mechanica*, 2. 850a, which says that if a uniform beam is suspended at the midpoint of its upper surface and is then tilted down at one end, more of its mass will then lie to the other end, and it will resume its original position if permitted. But if it is supported on a fulcrum at the midpoint of its lower surface, and similarly tilted, more of its mass will then lie to that end, and it will stay down at that end. The original *Mechanica* passage runs: "If the cord supporting a balance is fixed from above, when after the beam has inclined the weight is removed, the balance returns to its original position. If, however, it is supported from below, then it does not. Why is this? It is because, when the support is from above (when the weight is applied), the larger portion of the beam is above the perpendicular. For the cord is the perpendicular. So that the greater weight must swing downwards until the line dividing the beam coincides with the perpendicular, because the greater weight now lies in the raised part of the beam. Let the beam be a straight one represented by ΒΓ, and the cord be ΑΔ. When this is driven downwards the perpendicular will be represented by ΑΔΜ, if the weight is attached in the direction of B. The face B will then adopt the position E, and the face Γ that of Z, so that the line bisecting the beam at first was in the position of the perpendicular ΔΜ, but when the weight was attached took up the position ΔΘ. Consequently that part of the beam in its position EZ which is outside the perpendicular AM will exceed half the beam by ΘΠ. If, then, the weight is removed from the arm E, the arm Z must be depressed, for the arm E is the smaller. If, then, the cord is attached from above, the balance returns again to its original position.

If, however, the support is from below, the opposite results; for now the portion of the beam which is lower than the perpendicular dividing it is more than half; consequently it does not return to its place; for the part rising above is lighter. Let the straight beam be represented by ΝΞ, the perpendicular being ΚΛΜ, and this bisects ΝΞ. When the weight is attached to the arm N, N will take up the position P, while ΚΛ will go to ΘΛ, so that KO is greater than ΛΡ by ΘΚΛ. Now when the weight is removed the beam must keep its new position; for the excess over half the beam beyond K acts as a weight and depresses the beam."

The passages in Pseudo-Aristotle, *Quaestiones mechanicae* (or "*Mechanica*"), 847a28–b15 and 857a34–b8, cited by Nenci (94 n. 42), do not say precisely the same, making no reference to "the middle" and "the sides," and are indeed more convincing about the advantage of adding a weight at the handle end of a κηλώνειον (a "swing-beam," for hoisting a bucket out of a well, at 857a34) than Cardano is here.

of the waters themselves, further addition of weights to the handles makes the motion easier. And so it is feasible to propel the waters themselves up to a height solely through the impact of the waters flowing downward, and to irrigate fields with water from a lower level. But this is only possible in the case of waters that speed down, and possess an impact through their flow. To explain: let a machine of Ctesibius or of Brambilius or some other kind be installed at one side; there are, as I said, innumerable variants of these, although these two are neater than all the others, apart from the screw. And as I have already described, let the alternate &59 motion of the handle be produced by the action of a wheel with fins; thus water will come to propel itself upward spontaneously, because technical skill makes it act against its usual practice.[298] This pattern is followed by a number of cities that are situated on heights above a river.

After this, let us consider weights set on scales.[299] So let there be scales with their support[300] suspended at A, and an end where the sides of the beam[301] join at B, and a beam CD, and it is clear that CD moves round B, as a sort of centre, because CD cannot be separated from B. And let the angles ABC and ABD be right angles. I say that a weight placed at C will be heavier than if the scale pan[302] were placed in any other location, as if for instance it were placed at F. To enable us



to know that C &60 is heavier in that place than at F, it is necessary that it should move through a greater interval in relation to the centre in an equal length of time. In fact we see heavier things carried faster towards the centre of the earth, on the same basis as in the rest of things. I show on two lines of argument that this occurs more with a weight and the scale[303] placed at C than at F. The first line is that if during some period of time it moves from C to E, and the arc CE is equal to FG, because it will move down from F to G more slowly than from C to E, it will therefore be lighter at F than at C. Secondly, on the assumption that in an equal period of time it were to move from C to E and from F to G, still along the arc CE equal to FG, it would get closer to the centre than through a motion made along the arc FG. Consequently there are twin proofs that the weight will

298 "instituta."

299 "libra." The following discussion has profited from comments provided by Professor Alex Craik of the University of St Andrews, Scotland.

300 "trutina."

301 "lanx"—in effect here this is a line with zero thickness and mass, and Cass too calls this a beam. But normally the word means a "scale pan," and presently the same word is used by Cardano in that sense. It will be noted that at 65 (1560) a scale pan with mass is mentioned.

302 "lanx."

303 "libra"; Cass translates this also as "beam."

be heavier when the scale pan[304] is placed at a right angle to the support[305] than when it is placed anywhere else.[306]

The first one is explained thus. It is obvious in steelyards, and in those devices that raise weights, that the further the weight is from the support, the heavier it appears; but the weight at C[307] is distant from the support[308] by the length of the line BC, and at F by the length FP, but CB is greater than FP, from the fifteenth proposition of the third book of Euclid's *Elements*.[309] So when the pan[310] is placed at C, the weight will appear heavier than at F, which was the first proof. From this proof also it is clear that the more the scale[311] moves down towards &61 C from A, the heavier it makes the weight, and thus the faster it moves; but from C towards Q, contrariwise the weight is made lighter and the movement more sluggish, which experience too confirms. The second proof is demonstrated thus. Because CE for instance is equal to FG, let CH be taken equal to CE, and CH will be equal

304 The pan holding it; the word here is "lanx."

305 "trutina."

306 Nenci (95 n. 44) has identified an important source here, not named by Cardano: Jordanus Nemorarius. He lived in the thirteenth century; his biography is uncertain but his contributions to mathematics are substantial, especially the *Demonstratio de algorismo*, which details the Arabic number system and its use of integers, and his work on quadratic equations and geometry. P. Duhem (*Système du Monde*, 16 vols. [Paris: Hermann, 1913–1959], 1: 389–93) discusses the complex questions of identifying Jordanus and his works on statics. See also E. A. Moody and M. Clagett, *The Medieval Science of Weights* (Madison: University of Wisconsin Press, 1952), 119–227. The quotation from the *Liber de Ponderibus* of Jordanus provided by Nenci stresses the importance of the arc of a circle through which a weight descends, because there is more "violentia" in motion along a longer arc than along a shorter one, and there are seven assumptions ("suppositiones"): 1) the motion of everything that has weight is towards the centre (of the earth); 2) the heavier it is, the faster it falls; 3) it is heavier as it falls, the straighter its motion towards the centre is; 4) in relation to its position ("situs"), it is heavier the less oblique the descent from that position is; 5) a more oblique descent traverses less of the straight line, in the same amount ("obliquiorem autem descensum minus capere de directo, in eadem quantitate"); 6) in relation to its situation, one thing is less heavy than another insofar as the descent of the other follows on by contrary motion; and 7) the situation of equality is equidistant from the surface of the horizon. For further detail on Jordanus Nemorarius see http://www-history.mcs.st-andrews.ac.uk/Biographies/Jordanus.html. Last accessed on 26 June 2011.

307 The circle diagram above refers.

308 "trutina."

309 This states that "the diameter is the greatest straight line in a circle; and, of all others, that which is nearer to the centre is always greater than one more remote; and the greater is nearer to the centre than the less."

310 "lanx": Cass translates as "(end of the) beam"; note that this pan has no mass.

311 "libra"; Cass translates as "balance-arm."

to FG itself, hence the chord[312] CH is equal to the chord FG. Therefore, from the eighth proposition of the first book of Euclid's *Elements*,[313] the angle BFG will be equal to the angle BCH. It follows that with straight lines FL and HK drawn perpendicular, the angle FGL is less (since itself it was a part of the coequal angle BFG), from the fifth proposition of the first book of the *Elements*)[314] than the angle KCH. Therefore the side HK is greater than the side FL, for the straight lines FG and HC were equal, and the triangles right-angled.[315] Therefore BN is greater than OP, and consequently BM greater than OP. While then the scale[316] is moving from C to E, the weight moves down through the line BM— in other words,[317] it gets closer to the centre than it was at C, and while it moves through the interval of the arc FG and descends through OP—and BM is greater than OP. Supposing therefore that in an equal time it were to pass from C to E and from F to G, it still moves down faster from C than from F. Hence it is heavier at C than at F. From this is shown what the Philosopher[318] says, that if there are equal weights in F and R, the scale[319] still returns of itself to the position CD, where the support is AB.

312 "recta subtensa," which means the chord subtending a given angle at the centre.

313 "If two triangles have two sides of the one equal to two sides of the other, each to each, and have likewise their bases equal, the angle which is contained by the two sides shall be equal to the angle which is contained by the two sides, equal to them, of the other."

314 "The angles at the base of an isosceles triangle are equal to one another; and if the equal sides be produced the angles on the other side of the base shall be equal to one another." The relevance of this proposition is not apparent, although from the original diagram the statement is manifestly true.

315 Both the originally Greek ("orthogonii") and the originally Latin ("rectanguli") words are supplied here by Cardano.

316 Cass writes "end of the beam."

317 "seu."

318 Aristotle.

319 Cass writes "beam."

Jordanus[320] neither proved this nor understood it.[321] Similarly he did not prove why the support placed at QB &62 and below the pair of scales[322] itself, as occurs with the scales[323] upside down, provided you hold the support with your hand, when the scale is lying above a weight that had already descended after being drawn down to R, where something equal has been placed at F, or the scale pans[324] are entirely empty—not only do they not return to the position CD or that of the perpendicular; rather, R moves down more towards Q, and F rises towards A, as experience shows. This too Jordanus did not prove.[325] [326] Aristotle says this happens when the support is above the scales, because the angle QBF of the extreme position is greater than the angle QBR. And similarly when the support has been QB, the limit will be AB, and then the angle RBA will be greater than the angle FBA, but the greater angle will produce the heavier

[320] On Jordanus Nemorarius see n. 306 above.

[321] Nenci (97 n. 46) cites Jordanus Nemorarius, *Liber de ponderibus*, prop. 2, segn. B ii recto here, and says that "Rispetto a Giordano, il testo di Cardano offre sicurament un procedimento molto più semplice." And this verdict is supported, since Cass (180 n. 99) provides the solution of Jordanus at greater length (N.B. in this quotation the character *0* represents a symbol which she found too difficult to reproduce): "Cum equilibris fuerit positio equalis equis ponderibus appensis ab equalitate non discedet et si ab equidistancia sepe165etur (sic) ad equalitatis situm revertetur. Equilibris dicitur quum a centro circumvolutionis brachia regulae fuerit (Cass reads "fuerint") equalia. Sit ergo centrum *a* & regula *bac*, appensa *a b & c*. Circumducto igitur circulo per *b & c* cuius in medio inferioris medietatis sit *e*, manifestum quoniam descensus tam *b* quam *c* est per circumferenciam verus (=versus *e*), et quia aeque obliquus est inde decensus (sic) cum sit (=sint) equeponderosa non mutabitur alterutrum. Ponatur item quod submutatur ex parte *b* & ascendat ex parte *c*, unde dico quoniam redibit ad equalitatem, quoniam obliquior descensus est ab *c* ad equalitatem quam ab *b* ad *e*. Sumantur enim deorsum arcus equales quantitatibus qui sic *cd* et *bg*, & ductis lineis ad equidistanciam equalitatis quae sic *czl* & *dmn* item *bkb*, *gyt*. Dimittatur orthogonaliter descendens diametros quae sic *f0* malr (=maior) *yk* eritque *0m* maior *ky*. Sumpto enim versus superiorem partem arcu *cx* qui sit equalis *cd* & *bg* que ducta ex transverso linea *xrs* erit *rz* minor *0m* sicut declaratum est in Philotegni, et quia *r0* est equalis *ky* erit & *0m* maior *ky* & cum sit *zm* quod capit ex directo arcus *cd*, & *ky* quod capit *bg* equalis minus obliquus est decensus a *c* quam a *b* & ideo in altiori situ gravius est *c* quam *b* redibit ergo usque ad equalitatem."

[322] "libra": Cass writes "beam."

[323] "libra": Cass writes "balance."

[324] "lances": Cass writes "arms of the balance."

[325] On Jordanus Nemorarius (1225–1260) see n. 306 above. He did not prove the statement here, which is not true.

[326] Pseudo-Aristotle (*Mechanica* 850a3–29) demonstrates lucidly why a balance beam pivoted midway along its top edge is in equilibrium and will return to its initial horizontal alignment if disturbed, while if it is pivoted on its bottom edge it is unstable and will not do so. The accompanying figures (Loeb [Hett] translation, 349 and 351) make the argument easier to follow than Cardano's here.

weight. Hence with the support above F, R will be heavier,[327] so that F will pull the scale towards C, and with the support placed below, R will be heavier than F, so that it will pull the scale[328] towards Q.

But suppose anyone objects that the weight at F will be heavier than at C, with the support suspended at A, yet the opposite of this has already been proved. Our reply is, that the wider angle from the extreme position makes the weight heavier, provided the straight lines are [370]equal; but as has been shown, a weight at C is more distant both from the extreme position and from the beam than at F, so that the angle theory is not valid there, but when we put[329] weights in F and R, they are already equally distant both from the support and from the extreme position.[330] Accordingly then the angle theory &63 needs examination. So let the general theory be this: the further weights are from the limit or the straight or oblique (that is, at an angle) line of descent, the heavier they are. But at first the size of a straight line needs examination; when the straight lines are equal, then the larger the angle, the heavier the weight becomes.

If then BC gets curved towards QC,[331] it will be raised, and will be less far from the point B, and on that account will make weights lighter, and a gold piece of the correct weight will appear too light, and one too light placed on the opposite side will appear good. But fraud is revealed by an empty balance, or alternatively by interchange of[332] the coin[333] and standard weight.[334]

But why do weights seek to move towards the middle point of the world? This problem is readily solved if anyone bears in mind what we have said. For while a weight at F is arriving at C, it is getting nearer to the centre of the world, to which nature travels on the line PB. And while it is arriving from C at Q on the line BQ, and thus the weight's tendency[335] is to travel straight to the centre; in fact, since it is prevented by a restraint, it moves in the way it can move, and thus from the right or the left towards the perpendicular and middle.

But you will say, "Why is it then that when the scales are empty, C does not move towards Q?" I answer that then D would move towards A; but as has been

[327] N.B. here Cass writes, "when the support is above, F will be heavier than R, and therefore will impel [the end of] the beam toward Q."

[328] Cass writes "beam end."

[329] "comparamus."

[330] The word is "meta," here as just above.

[331] Interpretation is difficult; possibly Cardano means that the line BC will become convex downward, but C will stay on the same level ("elevabitur"; Cass agrees with the translation "will be raised," but "will be diminished" is also defensible) and thus will approach B. This paragraph first appears in 1554.

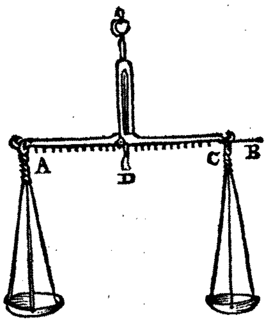
[332] "commutatis vicissim"

[333] "numus," for the more usual "nummus."

[334] "index."

[335] "intentum" as neuter is in neither *OLD* nor *L&S*—but "intento" is normal Italian.

seen on the basis of a straight line with C placed at Q and D at A, as much would still be lost on the D side as would be contributed to C itself. But what would be lost on the D side would be more contrary to nature than what &64 was contributed to C itself would be in accord with nature. So the hindrance would be greater than the help. Thus with equal weights present at C and D, they will not only not move away from that position of their own accord, but if forced away they will return.



When these lines of argument are considered, we can make scales[336] which will be seen to be equal when devoid of weights, and by appropriate[337] marks on the weights can represent a greater weight of the things themselves. In fact, as Aristotle states, sellers of purple used to impose on purchasers in this way. The explanation of this runs thus:[338] for a person seeking scales[339] that display twelve ounces instead of eleven, let a metal bar AB be taken, divided into twenty three equal parts (as this is the number &65 attained by eleven and twelve together). At the end of the eleventh and the start of the twelfth part, let the tongue and the aperture[340] of the balance be fixed. It is then evident that DC is greater than AD by an eleventh part; and as DC is a little greater than AD and heavier, we will make it lighter with a file or a drill, or we will add a lighter scale pan at C than at A, so much so that while the pans are empty, on the compensating basis of the length of AC and the thinness of DC,[341] the support[342] lies under the aperture,[343] with the balance not hanging down in any direction. But when we have added a weight of eleven ounces on the side C, and a standard weight[344] for twelve ounces in the

[336] "libra"—perhaps better, "a balance."

[337] "iustis."

[338] Pseudo-Aristotle (*Mechanica,* 849b31–850a2) puts it thus in the Loeb (Hett) translation: "This is how sellers of purple arrange their weighing machines to deceive, by putting the cord out of the true centre, and pouring lead into one arm of the balance, or by employing wood for the side to which they want it to incline taken from the root or where there is a knot. For the part of the tree in which the root lies is heavier, and a knot is in a sense a root."

[339] Better perhaps, "a balance."

[340] "agina."

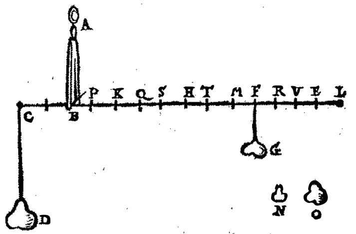
[341] The text reads, "longitudinis AC, tenuitatis pensata ratione," but since the mere insertion of "DC" after "tenuitatis" makes the sense clearer, I have included it in translation.

[342] "trutina"—this may possibly be the tongue.

[343] "agina."

[344] The word here translated as "standard weight" is "nota"; the texts consulted concur, and so it is in the nominative or ablative here, not the accusative, and its meaning is

pan A, the scales will display equilibrium. Since, then, the standard weights[345] have not been tampered with and the scales do not appear defective when the pans are empty, fraud comes clearly to light through interchange of merchandise and standard weights, the standard weights being in C and the merchandise in A. For the side C will move down for two reasons: because the greater weight is in its pan, and because CD is longer than DA.



More difficult and obscure is the case of the steelyard, on which we have written in *Arithmetica*.[346] But now, as this case is thus relevant to the present discussion, it will be an excellent addition, so far as the plan requires.

The whole case, then, consists in three items, of which the first is that of Archimedes in his *Parabolas*, and occurs where the bar[347] for a steelyard is reckoned as weightless. The ratio of weights &66 standing in equilibrium is that of the distances from the support they share. For instance, if D hung from the small pan at C is in equilibrium with G hung at F, and the ratio FB : BC is fourfold, the ratio of D to G will be fourfold.[348]

Secondly, when a weight has been hung on its own on the shorter portion, and the bar itself is weighty, of even magnitude and weight, and there is equilibrium, the ratio of the weight hung on to the weight of the whole bar will be as the differences of the parts of the bar to double the lesser weight. Example: let a weight D hung at C make an equilibrium with the rod BL without any other weight, and BL and BC are as I said, and let BK be equal to BC; then I say that the &67 ratio of D to the weight CL is like that of the weight LK to the weight KC.[349]

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unclear. It is used again twice very soon, as "notae." *L&S* and *Dictionarium LatinoGallicum* and *Ducange* do not offer any "nota" close to the "token/standard weight" of my guess. Cass just writes "a twelve ounce weight."

345 "notae."

346 In cap. 6 of this work of Cardano's, *De ponderibus*; the proposition is 45, "Rationem staterae ostendere," at *OO* 4: 481. The account is somewhat confusing, and is accompanied by a diagram which fails to indicate a significant location ("e").

347 "regula."

348 Nenci refers this to Archimedes' Ἐπιπέδων ἰσορροπικῶν ἢ κέντρα βαρῶν ἐπιπέδων, but also mentions *Quadratura parabolae* 6 and 8.

349 This can be expressed by taking moments round the fulcrum at B, and using s as the weight of unit length of the rod, D.BC = sCL.(CL/2— BC). Hence D/sCL = (CL/2-BC)/BC, or as Cardano puts it, = s(CL-2BC)/s(2BC).

From this the rule[350] is obtained: CL and CK are to be reckoned as of known weight, and we will calculate the weight D.[351] KL, which is to be 40, as an example in itself, becomes 1600; divide by the weight CK, which is to be 16—100 comes out; add the weight KL to this, which is 40; the weight D turns out to be 140.[352] And in this way we will be able, for whatever measurement we wish, to discover how much weight a steelyard registers.

A third case follows from these two, and is, that if a rod is reckoned as weightless, but from the part which is the distinguishing point[353] for lengths from the aperture an evenly distributed weight is extended along the whole rod, it will possess a heaviness equal to that of the same weight applied at a point distant from the balance beam[354] through the middle of the whole rod.[355] Suppose CL is a weightless rod, and CB is made equal to BK, and there is weight evenly disposed along it, so that in the form of a rectangle it creates an equilibrium with D applied at C, and G is taken as a balancing weight[356] equal to the evenly disposed weight, and let BM be half of the whole length CL: I say that G suspended at M will create an equilibrium with D, and so will be as heavy as the weight evenly disposed along the whole of KL.[357] Then suppose that at M it will be in equilibrium with D, therefore by the first of these propositions MB is to BC as D is to G.

Again, because D creates an [371]equilibrium with G extended along KL, then if an equal weight[358] were added along the whole of CK, it would still create equilibrium, because BC &68 and BK are equal, and then there would be a ratio of the weight D to the weight KL, the same as that of the weight LC to the

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350 "regula," which also means the bar of a steelyard, just above.

351 Repunctuating to read "... habendi, pondus D ducemus, KL (quae sit 40) gratia exempli in se, sit 1600 ..."

352 This too can be expressed thus; let D be the unknown weight, x be both the length and the weight of the segment CB = BK, and y be both the length and the weight of the segment KL. Then taking moments round B: $Dx + x^2/2 = (x + y)^2/2$. Hence $D = y + y^2/2x$. And if as stated, $y = 40$ and $2x = 16$, then $D = 140$ as Cardano says.

353 "differentia."

354 "librile"; Cass writes "fulcrum."

355 The thought is rather tortuous: Cass writes, "if the bar of a steelyard is assumed to be without weight, and if on one of the arms an evenly distributed weight is extended continuously along the bar, from its end over a distance equal to the difference between the lengths of the arms, it will have a gravity equal to that of the same weight suspended at a point which is a a distance from the fulcrum equal to half of the whole bar."

356 "aequipondium."

357 It is very difficult to interpret "KL" here unless instead "CL" is read, and then the proposition is much like the previous one. But it doesn't look as though that is at all what Cardano intends. Cass does not enlarge on this, and reads "KL."

358 "grave."

weight CK, from the second proposition substituted[359]—therefore the same as the ratio of the length LC to CK, because the weight is evenly distributed. But the ratio of the weight D to the weight LK is that of D to G, because it is supposed that G and LK are equal; therefore as LC is to CK, so MB is to BC; therefore by interchanging, as CK is to CB, so is LC to MB; but CB is half of CK, therefore BM is half of LC—QED.[360]

But because CB is half of CK, and BM is half of CL, it follows that MK is half of KL, and is as if it were suspended in the middle of the location over which it extends. So each single weight, according to Archimedes, however uneven, regarded as a triangle contributes the same amount of heaviness spread over the rod as if it were suspended from a centre at the place where the centre of gravity is located in relation to the vertical.

This he in general assumes, even if the weight does not extend right to the aperture,[361] but is extended for instance along LF, and its centre lies along the vertical[362] line E; then he says it is as if it were suspended at E itself.[363] From these considerations, as we have set them forth in the *Arithmetica*, the basis of creating steelyards is put together.

Now all that needs demonstration is how a steelyard may be brought to perfection, even if merchants dealing with costly merchandise use a balance.[364] Let the steelyard then be &69 divided in your fashion and have an auxiliary weight [G]; because G is movable, let G at F balance D itself, because thus D balances G at F, and in addition balances the bar KL.[365] Now let it be assumed that N is the part of D that balances LK, and O is the remaining portion of D, which balances G.[366] Therefore, in accord with the first rule,[367] the ratio of O to G is as that of FB to BC. But the ratio of N to LK is both as[368] LK suspended at M, from the third rule, and as that of LC to CK, from the second rule.[369] We shall

[359] Cass writes, "i.e. by substituting LC:CK for MB:BC in the second proposition."

[360] "quod erat demonstrandum."

[361] "agina."

[362] "directo."

[363] Nenci cites here Archimedes, *Quadratura parabolae*, 8, on which Cardano evidently drew here.

[364] "libra."

[365] Cass's 182 n. 113 has: "The bar-segment KL equals the whole right-hand arm (supposed of uniform weight per unit length) less the part BK, which is equal to the left-hand arm CB. Thus Cardan avoids consideration of that part of the whole beam which by itself would be in natural equilibrium."

[366] Cass adds, "at F" here.

[367] "regula."

[368] Cass inserts, "as that of N to."

[369] This is again very confusing. But it may perhaps be understood thus. Set out a straight uniform rod CL pivoted at B, and take CB as a distance c, BK a further distance equal to c, then KM a distance d and ML a further distance equal to d. Call the weight of

therefore establish the weight N at first on the vertical D, then when equilibrium has been established, the addition O is always in the ratio to G that the part LB is to BC. Therefore according to equal increments of BL,[370] O will increase, but N always stays the same, so according to equal increments of the parts BL, the weight D will increase. The steelyard would therefore become balanced if at C there is applied a weight creating equilibrium with LK; let us then divide the intervals from the aperture[371] to L by equal steps.

But because people do not apply a weight to it at C,[372] it is essential that the first mark (call it P) also shows the weight LK. Thus if LK were to weigh two pounds, and the weight D equalled two pounds, the mark of the first weight would be at K, for instance, but because G placed at K would weigh the equivalent of four pounds, and furthermore too LK creates a heaviness[373] of two pounds, D ought then to be four pounds, so the weight would be six pounds, yet would &70 only show four pounds.[374]

For this reason we will make the first mark of four pounds at P, since when hung from there, G creates a heaviness of two pounds, and LK two more, so the weight D will be of four pounds, which will create equilibrium. Therefore the mark of four original pounds will be at P, and at a much smaller interval from the balance point[375] than the rest display between each other. But the rest will in fact be equidistant from each other, for instance the second at Q, the third at H, the fourth at M, the fifth at R, and the sixth at E.[376]

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the rod per unit length s. Since N is the part of the weight D applied at C which balances the KL part of the rod, N.c = s.LK.(c+d). And the whole rod's weight s.LC/CK = s(2c + 2d)/2c. Hence N/LK = s.(c + d)/c—and so does s.LC/CK.

370 Here it is difficult to follow the intention and the argument. The underlying obstacle to comprehension is that for Cardano, BL and any similar item may represent either a distance or a weight—the weight of the portion of the bar from B to L. In the note above, I have represented the weight as s.BL, where s is the weight of unit length of the bar, and the bar is regarded as homogeneous and uniform from end to end. I suggest that part of the intention is to *design* a steelyard. In that case, lengthening BL need not necessarily increase its moment round B, which would obviously destroy the equilibrium between N and LK. It might be thinned, or something of that sort. Cass says here that the "equal increments of BL" are "of the distances between F and B."

371 "agina"; to Cass here, "fulcrum."

372 I.e. exactly at the end. Cass writes, "since these divisions themselves will not place the weight at C—i.e., determine C—it is necessary that the first mark—suppose that it is P—indicate also the weight of LK . . ."

373 "gravitas."

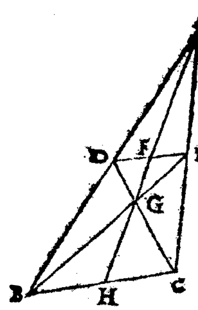
374 I cannot yet follow this, and Cass is certainly unfaithful to the original here.

375 "fulcrum" (Cass).

376 I think this is true. To get away from Cardano's symbols: with a steelyard of uniform weight and dimensions, and pivoting at a point in its midline, let the weight to be measured be x, applied at a fixed distance k from the fulcrum. Let the (constant) test

Consequently when G is placed at E, it will show twenty-four pounds. And from this it is evident that no small benefit accrues when G is a weight itself known, for instance one pound, or two pounds, or three.

The centres of gravity in circles and rectangles are at the intersection of two diameters. And in all equilateral figures capable of being inscribed in a circle, the centre of gravity is the same as the centre of the circumscribing circle. It is assumed in all cases that these weighty items have everywhere the same thickness and are made of matter of uniform heaviness. In all triangles the centre of gravity lies at the intersection of three lines, each running to one side from the opposite angle and dividing that side equally. They must &71 coincide at a single point when intersecting each other, though Archimedes turns out not to have proved this. In our *Geometrical Elements* we show this in general, but it will have to be made clear now.[377] Bisect the sides AB and AC equally at D and E; draw CD, BE, and through their intersection [G] AGH, and DE, which will be parallel to the third side. Hence BEC and CDB will be equal, being on the same base BC; when the shared BCG is removed, CEG will be equal to DBG, and AGE and AGD respectively are equal to it because they are on the same base and between parallels; so AGE and AGD are equal. And as they lie upon the same line AG, they will be of equal height, which is also the height of the triangles FGD and FGE, which lie on the same base FG, so they too are equal to each other. And because BC is parallel to[378] DE, then from proposition 29 of the



weight be l, applied at a variable distance y from the fulcrum. Let the (constant) weight of the bar be m, applied at its centre of gravity at a fixed distance n from the fulcrum. Then initially

$kx = mn + ly$ (k, l, m and n constant)

Then add, say, 4 to x.

Then for equilibrium, $k(x+4) = mn + l(y + 4k/l)$

and with minimal conversion, the *change* in y is $4k/l$,

which is constant for x changing from 4 to 8, 8 to 12 etc., but not the same as the change in moving from $x = 0$ to $x = 4$, which is $(4k + 2mn)/l$.

[377] Nenci cites here Archimedes *De planorum aequiponderantium*, Bk 1, props. 10 and 11–14, and the proposition that they meet at a single point is not there actually proved by Archimedes, who possibly thought it self-evident; I don't see in Nenci a statement about where it was so proved, or by whom, in the extensive quotations provided. He mentions that Cardano had published from 1534 *Novae geometriae libri quindecim*; Maclean, *Girolamo Cardano De libris propriis*, M27, 58–59, describes the scope of this work, which Cardano modelled on Euclid, as it is set forth in *De libris propriis*, but the work does not appear to have survived.

[378] "aequidistat."

first book of the *Elements*[379] and proposition 15 of the same book,[380] DGE and BGC are equiangular, and the ratio of BG to GE is equal to that of CG to GD. From the same propositions BGH and GEF are similar, as are CGH and DGF. Hence the ratio of the triangle BGH &72 to EFG is as the ratio of BG to GE squared, and of CGH to DFG is as CG to GD squared;[381] and as already said, CG is to GD as BG is to GE, hence BGH is to EFG as HCG is to DFG; hence, since DFG and EFG are equal, BGH and CGH will be equal; and since they lie between parallels, BH and HC will be on equal bases, so all the triangles ABH, ACH, CDB, CDA, BEC, BEA, will be the halves[382] of ABC; hence a triangle poised at G will not be able to tilt in any direction.[383]

And the centre of gravity of a parabolic section[384] or rectangular cone is in its diameter which runs from its summit to the middle of its base at the point which is distant one half more from the summit of the cone than from its base, which is the straight line [372]lying below the angle of the cone.

[379] "If a straight line fall on two parallel straight lines, it makes the alternate angles equal to one another, and the exterior angle equal to the interior and opposite angle on the same side; and also the two interior angles on the same side together equal to two right angles."

[380] "If two straight lines cut one another, the vertical, or opposite, angles shall be equal."

[381] From Euclid VI. 19: "Similar triangles are to one another in the duplicate ratio of the corresponding sides." (Heath, *The 13 Books of Euclid's Elements*, 2: 232)

[382] "medietas."

[383] Which shows that G is the centre of gravity.

[384] The language here is imprecise: "Centrum autem sectionis parabolae seu coni rectanguli est in eius dimetiente . . ."—a parabola *is* a section of a cone, so the sentence might properly read, "Centrum autem sectionis coni rectanguli seu parabolae est in eius dimetiente . . ." Nenci (107 n. 58) cites the Latin translation of Archimedes *De aequiponderantium,* 2. 8, which does not specify *which* conic section, but reads better than Cardano: "Cuiuscunque portionis ad recta linea et rectanguli coni sectione compraehensae, centrum gravitatis dividit diametrum portionis, ita ut pars eius ad verticem terminata, sit ad partem eam sesquialtera, quae ad basim portionis terminatur." The stated proposition certainly comes to that conclusion, by geometrical methods which I cannot properly follow, but the figure in *Les oeuvres complètes d'Archimède* (Brussels: Desclée, de Brouwer et Cie., 1921), 337 shows a most asymmetrical parabola, which I don't understand. It *does specify a parabola*, which Cardano does not.

This result (that the distance from the apex of a parabola to the centre of gravity of a portion of the parabola defined by a line across it parallel to the tangent at the apex has a ratio to the further distance from the centre of gravity to the line that is 3 : 2) can be conveniently reached since the development of the integral calculus, by integrating the moments of vanishingly thin slices of the section of a parabola around a line parallel to the baseline of the portion.

And so when a uniform rod CL has been set in place weighing seven ounces, and balanced[385] at B, so that KL is 10 and KC 4, and G one pound, we shall establish a steelyard thus. I shall square[386] a weight LK, which is 5 in itself, it becomes 25; I divide by the weight KC, which is 2, to make 12½, to which I add 5 ounces, LK, to make 17½.[387] So I will place at CD a five and a half ounce iron shackle, and a weight of one pound LK will be left behind.[388] Then when we have placed G at K, it will be equal to a pound,[389] and the addition of another pound will be needed at D because of LK, so at K we will show two pounds, and make a mark accordingly. Thereafter at S, 3; at T, 4; at F, 5; at V, 6; at L, 7, at equal intervals. From this it is clear that &73 all these intervals can be allocated according to ounces, except BK, the first. Still, we could divide it too, so that a pound is indicated at B, and at AB in K ounces added will be indicated[390] by equal intervals, first, 13 ounces, the second, 14, the third 15, and so on for the others.[391]

This shows why balances are more precise than steelyards, for three reasons. This was my aim from the start. In fact it is difficult in a steelyard to create a beam so precise in size, and even if it is so in size, it will not be so in weight—indeed we can hardly achieve this. Secondly, it is very hard to divide LB entirely at equal intervals to perfection. Thirdly, the weight is not often attached at the very end C as a rule, and when it is attached further in, it creates confusion.[392]

There are also many additions which impair a steelyard, none of which occur in a balance. This is why costly items are not usually assessed in a steelyard, but on a balance. The precise construction of the steelyard matters a great deal, that G should be light, and also LC, and that LB should be thrice BC, for thus LK will be equal to KC, and that the shackles CD should be at the end of LC, and of equal weight to LK, since that kind of steelyard will closely match a balance.

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385 "librile"—Cass translates as "balanced" and must be right, though classically this meaning is not listed in *OLD* nor *L&S*.

386 "ducam . . . in se . . ." evidently means "I shall square . . ."

387 Cass says that the Figure here is the steelyard one with a large number of characters on the right side of the horizontal bar, and the rule used is that on her page 126 (around 67 [1560]), "namely, that at equilibrium $KL^2/CK + KL = D$."

388 Cass: "Then I subtract the weight of the connection CD, which is 5½, and thus determine the excess weight on the arm LK, which is one libra."

389 "libra"; at 889 (1560) in Book XIII Cardano says that "pondo" and "libra" are the same.

390 Translating "significabunt" as if it read "significabuntur."

391 I cannot follow this—the magnitude of the weights and their distance from the fulcrum and the role of the rod's weight are unclear.

392 The text runs: "Tertio pondus raro in extremo C appendi solet, quod cum citra appenditur, confusionem parit." I take the meaning shown, instead of "it is rarely attached . . . because when it is attached further in, it creates confusion."

Experience &74 shows how much weight leather bags can support for the construction of bridges;[393] a bladder full of air with a capacity of five pounds and an ounce of water was supporting fourteen and a half pounds of bricks; it follows that in river water, bags can hold up thrice the weight of the water they can contain.[394] Nor should we ignore that it follows from the theory of density that while people support themselves on their backs in water, like jesters on ropes motionless and unbending in any direction, they do not get sunk at all at the time.[395] But this, in itself a very difficult feat, gets even harder through the movement and irregularity of the water. And let this close the account of the principles of mortal[396] things.

[393] Arrian (*Anabasis*, 3. 29. 4 and 5. 12. 3) mentions two occasions on which Alexander the Great's armies used inflated leather bags to cross rivers, and Xenophon (*Anabasis*, 1. 5. 10) mentions one such occasion when his troops crossed the Euphrates in 326 B.C. using leather bags filled with hay to maintain the volume and buoyancy of the bags.

[394] Bags can hold up only the weight of the water they can contain; but whatever they are holding up, as Archimedes stated, if itself submerged in water, presents a weight diminished by the weight of the water the load displaced—i.e. by its weight divided by its specific gravity. Ignoring the ounce of water, Cardano's figures indicate a specific gravity for brick of 1.53; I obtained a value of 1.71 by weighing and approximately measuring a common building brick here. Tartaglia died at Venice in December 1557; "among his posthumously printed works was the first experimental table of specific gravities of materials" (S. Drake and I. E. Drabkin, *Mechanics in Sixteenth-Century Italy* [Madison: University of Wisconsin Press, 1969], 25).

[395] Nenci (108 n. 60) draws attention to several contemporary illustrations of river-bridging techniques using inflated leather bags.

[396] And therefore corporeal.

&74 Book II. The Elements, and Their Movements and Actions

And now let us deal with the elements, which are constituted by form and primary matter, and appear as though endowed with soul; the Greeks call them στοιχεῖα. The first thing to grasp thoroughly is, how many there are, and of what kind. Aristotle reckons four: earth, water, air, and fire. Firstly, there are in fact four primary qualities. They alone do not constitute an element, because they do not possess the power of acting and of being acted upon; &75 and there cannot be more than two present at once without contraries existing together. For out of hot, cold, dry, and moist, if you somehow freely accept three, you must accept contraries. But hot cannot be combined with cold, nor dry with moist. Therefore, when a pair of non-contrary qualities are linked, only four combinations will exist at one time, which constitute the four elements.[1] Also, between the lowest and the highest position, essentially two positions must intervene, the lowest not precisely, and the highest, and hence the same number of simple bodies. And if plausible evidence achieves anything, we also see in actual mixed bodies the four elements. For no one can be in doubt about earth, air, and water, in view of their size, and huge masses, of water (like the sea), of air, and of earth in the universe. In the case of fire, we see its increases, its power, and its singleness of nature; further, its wellspring is supposed to be under the lunar concavity. Many people too think that these four are visible in distillations.[2] And our senses detect the same number of humours in animate beings.[3] Again, many people consider that the reason why comets occur is that vapours are kindled under heaven from

[1] Aristotle (*On Coming-to-be and Passing Away*, 2. 3. 330a30–b1; Loeb 275) makes this point; he distinguishes four "qualities" (hot, cold, wet, dry) and notes that there are only four possible combinations of these four, each describing one of the four στοιχεῖα or "primary bodies" (fire, air, water, earth).

[2] I suppose that these distillations were intended to extract the essence of whatever was being sought, and so it would not be surprising if the contained elements became more obvious.

[3] "animalibus."

the element of fire.[4] But certainly there is no lunar fire under heaven, for heaven being a very pure thing, it was inappropriate to locate extremely hot items under a thing devoid of any quality. Nature in fact always links extremes to middling things:[5] membrane &76 between flesh and bone; cartilages between bone and ligament; she has placed a double membrane between bone and brain, because brain is softer than flesh, and the harder membrane is placed closer to the bone.[6] And speed of movement cannot be either the cause or the proof of heat. For even if things that are compact[7] are set on fire by movement, as stones, lead, and animate things are, things that are diffuse get colder the faster they move, as water and air do; all strong winds are in fact cold, and rivers that flow swiftly have very cold water.[8] Another potent argument, too, on this is that [373]comets or meteors kindle heats these things cannot endure. So what will happen if such a large area and the whole globe is ringed with fire? What will prevent it kindling the very air, and then everything that is left, especially when the stellar heat will assist? It is true that Averroes supposes that all light is hot;[9] people are very keen that air too is hot; but the moist quality resists least of all. So how will the very air defeat the most violent and greatest and most active of the elements? Observing this, Averroes himself said that there are times when fire is not actively hot; but

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[4] On this see Aristotle, *Meteorologica* (I. 7. 344a8–15; Loeb 51): "We have laid down that the outer part of the terrestrial world, that is, of all that lies beneath the celestial revolutions, is composed of a hot dry exhalation. This, and the greater part of the air which is continuous with and below it, are carried round the earth by the movement of the circular revolution: as it is carried round, its movement frequently causes it to catch fire . . . which we maintain is the cause of scattered shooting stars." Nenci cites Agostino Nifo on this too, who uses the phrase "hot dry exhalation" for the fiery contribution, and adds to it a "larger measure of air" for the generation of comets. Cardano's conversation with the "erudite and clever young King" Edward VI of England in 1552 included the subject of comets (Grafton, *Cardano's Cosmos*, 115).

[5] Nenci (117 n. 4) traces this concept back through Albertus Magnus and Avicenna.

[6] The membranes surrounding the brain are traditionally named the *dura mater* (tougher, and lining the skull internally) and the *pia mater* (delicate, and covering the brain).

[7] "constant."

[8] Nenci (117–18 n. 5) cites Aristotle, *De caelo*, 2. 7. 289a19–32, where it is mentioned (289a24–7; Loeb 179) that the leaden parts of projected missiles may melt. And Guthrie's translation (180 n. "a") mentions numerous references in Latin literature to this supposed phenomenon. But Aristotle does not here refer to moving water or air becoming *cold*. Ioannes de Ianduno (cited by Nenci), whose comments were published in 1564, does note that flowing water grows cool.

[9] Nenci here cites the commentary of Averroes on Aristotle's *De caelo*, 2. 7, 289a19–32, which refers to rays from heaven (Sun and stars), which "calefaciunt per se, et non esse corpus eos declaratum est, nedum ut sint corpus calidum," but the question of whether light in general is hot is not addressed.

if it is not actively hot, what potentiality is this?[10] We call "potent" the medicaments that warm when consumed; but will this fire be consumed by some huge &77 animal? Again, if fire is not hot nor water, on the same basis, cold (this is to muddle the order of the universe), what prevents it[11] from glowing? But people deride this as a trivial argument. Again, if there is fire there, why does everything seem colder the higher up we go, so that people say there is plenty of snow at the tops of mountains even in the torrid zone? This is less remarkable if one bears in mind that snow is not confined to winter, but even in midsummer freezing hailstorms are created.[12] But people say that these regions are away from the impact of the rays; but that is an argument for less hotness, not for coldness. Finally, if fire were there, its particular purpose would be generating, but this cannot be so, because it is the heat of heaven that generates, as indeed the Philosopher himself attests,[13] and something very light in weight cannot descend so far. There may be someone who will say that this fire is conveyed upward, and will therefore surmise that its place is there. But in the first place, these rhetorical arguments are unfit for serious presentation. And this fire's nature is not the one they attribute to that loftier fire, since it burns, glows, destroys, none of which they attribute to that one.

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[10] marginal: Primo canticae commento 15. Nenci cites Averroes-Avicenna, *Cantica cum Averrois Cordubensis commentariis* (besides his *Canon*, Avicenna wrote his *Cantica*, and Averroes commented on the latter) in Latin translation, part 1, section 1, "*De complexionibus in se*"; in this passage, it is not that there are *times* when fire is not actively or actually hot, but there is a *place* "super aerem in concavo orbis coeli" where it is not.

[11] "quid etiam prohibet ne luceat?" What is prevented from glowing is presumably water; if Cardano had inserted "eam" this would have become clear.

[12] Aristotle (*Meteorologica*, 1. 12, 348a15–38; Loeb 81–83), addresses the problem of summer hail, holding that experience indicates that it forms at a relatively small height above the earth.

[13] "Now so far as we can see, the faculty of Soul of every kind has to do with some physical substance which is different from the so-called 'elements' and more divine than they are . . . In all cases the semen contains within itself that which causes it to be fertile—what is known as 'hot' substance, which is not fire nor any similar substance, but the *pneuma* which is enclosed within the semen or foam-like stuff, and the natural substance which is in the *pneuma*; and this substance is analogous to the element which belongs to the stars [the "fifth element"; the other four are found in the sublunary regions, though Aristotle calls it first of the elements ("more divine . . . and prior") in *De Caelo* (1. 2; Loeb 15)]. That is why fire does not generate any animal . . . whereas the heat of the sun does effect generation, and so does the heat of animals . . . Consideration of this sort shows that the heat which is within animals is not fire and does not get its origin or principle from fire." (Aristotle, *De generatione animalium*, trans. Peck, 2. 3, 736b30–737a7; Loeb 171)

We shall also go on to say why this[14] happens, and will show that it does not always happen either. The evidence does not prove that—rather the opposite; for between &78 two extremes two midpoints are not normally identified, but only one. If that is established, there will not be four elements, but only three. But if it does not prove that, much less will it prove that there are four. Neither meteors nor comets convey to us that there is fire there, since the Philosopher[15] himself states that these very things occur in the air below fire and adjoining earth, so that they have absolutely no need of fire.[16] Fire is not visible in mixed bodies either. For if in fact it were so, it would rather exist in spurge and pepper, whose power is hot, and considerably dry, than in the coldest stones. Distillations too only display three substances: water in the role of water, oil instead of air, and earth which settles to the bottom. But if you say that the redder part of the oil represents fire, [17] being very pungent, we reply (and earnestly) that this pungency and sharp taste originates from the rather keen power of fire. The evidence is, that no part of the oil of metals is devoid of a very sharp taste. Consequently, if all of this that is very sharp relates to fire, there should be no air at all within it. Consequently too, we come back to just three elements.[18]

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[14] Evidently the "burning, glowing, and destroying."

[15] Aristotle.

[16] That they have no need of fire is Cardano's conclusion, not Aristotle's; Aristotle (*Meteorologica*, 1. 7, 344a17–18; Loeb 51) locates these phenomena as Cardano says, but affirms that they are due to the impact of a "fiery principle" (ἀρχὴ πυρώδης, or "principium igneum" in the Latin translation).

[17] For citation of authorities on distillation contemporary with Cardano, see Nenci, 121 n. 13. Biringuccio (*Pirotechnia*, Bk IX cap. 2; trans. Smith and Gnudi, 339) wrote that the oil came from fire: "Since everything that is found created under the heavens is nothing but elemental substance or composed thereof, it is always possible to think that water and air can be extracted from the wateriness or airiness that it contains, and from the fieriness, oil, and a certain power, almost animate, which they call spirit; and that part of these things that remains coarse and arid in the bottom of the vessels is surely recognized to be earth." Ulstadt (*Coelum philosophorum*, 111) also is not in accord with Cardano, and refers to a reddish oil in which the element of fire and water is present; he is engaged in preparing *aurum potabile* and extracting qualities other than the Fifth Essence. Truly, as Biringuccio (*Pirotechnia* IX. 2, trans. Smith and Gnudi, 339) remarks of distillation, "When you thought you were doing one thing you would do another, even though the material were disposed for what you wish."

[18] Theophrastus (on whom see n. 21 below) had long before proposed the relegation of fire from the list of the four elements (*De Igne,* Turnebus translation, originally published in Paris in 1553). He pointed out how fire can be generated in various ways, and destroy itself; it needs feeding, and is manifold in species and diverse in power. It stays in a passive subject and changes it. Its action varies with season, light, access of air, and other features. The allied heat is altered by many circumstances (its measurement lay in the future beyond Cardano's time). Its appearance is highly variable and inconsistent. It is notable that Theophrastus was familiar with the generation of fire by rubbing sticks.

The humours in animate creatures are four in number. But how does this relate to the elements? What if I am to say that there are only three, following Thrusianus,[19] the expounder of Galen's art of medicine?[20] Yet our senses show that there are four. Not at all; even they do not assert that this fire is an element. &79 So our senses make plain that there are three rather than four. Nor is fire to be reckoned an element because it rapidly consumes everything—on that basis, even movement is an element. Nor is fire an element because it rapidly increases—even mice would then be one. But neither of these is associated with earth, which everyone combines to reckon an element. So for showing that there are four elements, and that fire too is an element, all these points carry too little conviction. Not only so, but they show rather the opposite, as we maintained from the start. This important item was left over from the combinations of qualities. But people do not see it show in mixtures; for there are some hot and wet things, some hot and dry ones, and so forth. But since among the elements heat and such excessive dryness were all to be turned over to destruction, this replaces the element by celestial and well-tempered heat, from which everything is created. In fact the matter people call fire is then normally produced from this and from decay, in a process of motion. So let there be fire—but not at all as an element.

Now I know what some folk are about to say, "Who are you, so bold as to dare to differ from the Philosopher, especially in so well and long established a view? Then, in what way will the creation of hailstorms and snow show that fire is absent there, since even if no fire is present, it is &80 still not credible that the region in question is very cold, for it is illuminated by the sun's rays, and nevertheless the very air bathing that region is very warm? When we speak of fire and the element, we mean an exceedingly hot and dry thing; this fire of ours is very hot and very dry, hence it is also not mixed, because if it were, it could not be like that— hence this fire is an element."

Though this is not dragged up against me, I still feel it could be. So, to get to Aristotle, he was human, and in dissection and in many details he went astray.

For the poet John Donne's reference to the removal of fire as an element, see n. in Book I at 6 (1560).

[19] Nenci (121 n. 14) identifies this character as Turisanus de Turisani [Torregiano de' Torregiani] and cites from his *Plusquam commentum in Microtegni Galieni* published at Venice in 1498 to the effect that the humoral contents of the veins comprise earth, water, and air, and referring to Galen 2° *De naturalibus virtutibus.* Torregiano or Tur(r)isanu was born in 1270 near Florence and died in 1350. He was a physician with exceptional command of Greek, and wrote a commentary (he was described as "more than a commentator") on Galen which was first published at Bologna in 1489 and went into 7 more editions (*Biographisches Lexikon*, 2nd ed.).

[20] Siraisi (*The Clock and the Mirror*, 64) points out how carefully Cardano guarded his medicine from the extreme consequences of his element theory, by preserving four humours yet adopting three elements.

Further, his successors and Theophrastus[21] and Galen wrote much that was erroneous, and if it was all right for Aristotle to desert Plato in the cause of truth, why will it not be all right for us to desert him in the same cause? He attempted to construct some general propositions which experience shows to be erroneous, for instance that no animal smells pleasant,[22] and that a heavy thing cannot project on both sides, and consequently the earth does not project over the waters from both sides[23]—things which experience nevertheless reveals to be false.[24] And so, if we accept that among a thousand propositions he went wrong in two or three, we shall not reckon that he did something unworthy of a human being, and a very wise one too. Indeed, by Averroes himself he &81 is abandoned at a few points, he is confuted at some points, but at more points he is defended with some transfer of meaning. This too is really to show him up, not to support him. But even here we do not differ from Aristotle: for inside the concavity of the Moon's sphere, he does not wish fire to exist, nor any very hot thing.[25] So far as the region [374]of air extends, it is obviously very cold, because as we shall show, all the elements are like that.[26] In fact what is said about vapours and the so-called antispasis[27] resembles a fable more than an account of a natural thing.

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[21] Theophrastus (ca. 370–288 B.C.) was a disciple and successor of Aristotle, who especially investigated plants. For a general assessment of his work, see A. G. Morton, *History of Botanical Science* (London: Academic Press, 1981), 29–43.

[22] Pseudo-Aristotle (*Problemata,* 13. 4, 907b35–908a19; Loeb 307–9) makes one exception; he excludes the leopard (πάρδαλις), which "is pleasant even to beasts, for they say that other beasts enjoy sniffing it." There is a minor divergence here between Pseudo-Aristotle's "καὶ αὐτοῖς τοῖς θηρίοις" and the very valuable translation of Theodore Gaza (1537), cited by Nenci (123 n. 15), which reads "non nisi bestiis" (i.e. "only to the beasts"). Pseudo-Aristotle holds that animals in general smell unpleasant "because of unabsorbed waste product," while plants in general smell pleasant. Theodore Gaza (fl. 1478) was born at Salonika early in the fifteenth century, and flourished for a time at Constantinople; then, like so many of his countrymen, he started for Italy long before Constantinople's capture. At the Papal court of Rome, he translated all the works of Aristotle. See A. Kazhdan and A.-M. Talbot, "Gazes, Theodore," in *Oxford Dictionary of Byzantium,* 3 vols. (New York: Oxford University Press, 1991), 2: 825–26.

[23] The argument is unclear.

[24] There is discussion of the point about the earth emerging from the waters later on, at 216 (1560), which see later.

[25] Aristotle, *Meteorologica* (1. 4. 341b13–18; Loeb 29–31): "And therefore the region round the earth is arranged as follows: first, immediately beneath the circular celestial motion comes a warm and dry substance which we call fire . . . below this substance comes air."

[26] Aristotle in *Meteorologica* (1. 3, 340a24–32; Loeb 17) states that this upper region is so far from both stars and earth as to be cold, but does not mention elements as cold.

[27] This word appears first in Hippocrates, where (*Humours,* I) it refers to diverting things back to where they came from, and (*Regimen* II. 56) to a reversal of a previous flow, but with no particular reference to humours. In Galen (*De methodo medendi*, V. 8,

If then fire is placed in the concavity of the Moon, and is reckoned to rotate rapidly there, it will be extremely cold. So we attack this view, and do not abandon experience. For it is clearer than light that the air there is very cold, and more so the air in the Moon's concavity; but it is tempered by nearness to the stars,[28] and especially to the Moon. And though the Moon directly faces only one small part, yet since it is all mingled together and of very rarefied substance, that air is the most temperate air; it is the purest and most transparent, and all of it unclouded. That is why the Ancients called it the Ether, and they were right, and furthermore the Philosopher himself sometimes called it that.[29] It suits very neatly the place and nature of heaven, being almost like it in its rarefaction and temperament of quality. In fact the Ether is not tempered in virtue of being equally mingled from hot and cold, but because &82 it is devoid of both these qualities. Likewise, it cannot be termed dry, because it flows, nor wet, because it does not moisten—but pure, as I said, and unclouded, and it is well suited for generation,[30] which we shall discuss later.

That air is very hot is not shown by any experience or reasoning, but rather that of itself it is very cold. And all this is concordant with experience. Those monstrous comments of the Aristotelians (let me not appear to accuse Aristotle himself) upon inexplicable problems which are still open are brought to a close. It is better, then, to guard the truth and experience itself by sticking to a few stable points, than to remain in ignorance while forever trifling with those people about the nature of things. For who but a madman would listen to anyone debating and asserting that air is hot at its top and boundary, and then because of its motion alone, or its vapours without motion, as during a northerly wind, it gets

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K. X. 315 and 341, and especially *Ad Glauconem de medendi methodo* [II. 4, K. XI. 91]) there are two options to cope with harmful humours: repel them to their source if they are accumulating round a part (*antispasis, revulsio*), or divert them elsewhere if they have already taken possession of one (*parocheteusis, derivatio*); Galen's original text reads: τῶν μὲν οὖν ἔτι ἐπιρρεόντων ἡ ἀντίσπασις, οὕτω γὰρ ὁ Ἱπποκράτης ὀνομάζει, τῶν δ' ἤδη κατειληφότων τὸ μόριον ῥευμάτων, ἡ παροχέτευσις ἴαμα. The word also appears on 116 (1560) of the present Book, where Cardano's use of it seems much less precise. On the closely similar word *antiperistasis*, see n. 322 below.

28 Aristotle and Cardano use the word to cover both stars and planets (Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 103).

29 This is cryptic, but may be understood by reference to Aristotle (*Meteorologica*, 1. 3, 339b26–28; Loeb 13): "For men seem to have supposed that the body that was in eternal motion was also in some way divine in nature, and decided to call a body of this kind aether, as it is different from all terrestrial things." Lee in n. d to the Loeb translation remarks that the reference is "as if αἰθήρ were derived from ἀεί and θεῖν ["always run"], with a play on θεῖος ["divine"] as well; for this etymology, cf. Plato, *Cratylus* 410B, Aristotle, *De mundo* 2. 392a5."

30 Scaliger (*Exercitatio* 10 [53]) protests that such cold items could not be suited for generation.

so cold that it gives rise to ice, snow, and hail, and no one would have grumbled about the air's heat apart from the Sun's power, but everyone grumbles about cold, and yet they dare to allocate to air the same heat as to fire. Since fire is of a more rarefied substance than air, why does it never depart from its huge heat, nor does its nature and burning grow gentler?—I will not mention its getting cold.

But if they say that this air is not the air that is in motion or that has room for vapours, it is actually &83 impossible for its substance to continue after such a great transformation from very hot to very cold, even Aristotle being the decisive voice. This is obvious, since all the air around us is cold or anyway temperate, being located beside the Moon's heaven; for the whole mass of air, being frequently derived from ethereal flames, revolves over twenty-four hours with the heavenly motion, because even Aristotle himself grants that this whole machinery of the air is cold or temperate.[31] If this is not air, we need to look for another air, maybe above heaven, or in the bowels of the earth.

There are then three elements:[32] earth, which is the most compact and the heaviest, and located at the bottom; air, which is the most rarefied and the lightest, situated at the top; and water, which of them all occupies the middle position between these.[33] Common to them all is their absence of innate heat, for there is no heat except from heaven, and therefore from a soul or light. Earth, being too dense, and air, being too rarefied, appear as less cold; but water, being of a medium substance, appears very cold. Thus air on growing heavier appears colder. But if it is not influenced in such a way, it is held to be temperate on account of its rarefaction, yet it is not. But it has a potentiality of this sort, just because it is easily altered. In addition, when cold things grow more dense of themselves, they get colder, as in the case of ice. But earth accommodates &84 heat because of rarefaction, and therefore is reckoned less cold; that is why rocks are themselves much colder. Air, however, is temperate, so to speak, because of light, and being readily altered on account of rarefaction, is judged not only minimally cold, but even hot, since all the elements are equally very cold of their own nature. The evidence is the regions under the Bear, and nighttimes, and mountain summits—but reason too demonstrates this; all heat is from the stars. Because the elements are pure, they are devoid of heat from the stars; stellar heat produces instant change, and what is changed differs from what it was before.

[31] But the diurnal revolution can cause it to take fire; see Aristotle, *Meteorologica* (1. 7. 344a8–15; Loeb 51), cited on 75 (1560) above.

[32] On Cardano's modified system of the elements, see Schütze, *Naturphilosophie* (100 ff.). Material to [A] on 86 (1560) first appears in 1554, replacing text of Appendix 1 available in Nenci, 315.

[33] Scaliger (*Exercitatio* 9 [46]) hotly attacks Cardano's standpoint about fire not being an element: "videris uti verbis acrioribus imò verò atrocioribus, ac penè tragicis." And in *Exercitatio* 10 (55), he says that all Cardano's defences on this point crumble under assault.

Consequently an element from a pure and altered thing will be mixed—it will not be simple. All the elements then are very cold, that is, devoid of all heat. In fact, coldness is nothing other than deprivation of heat.[34] They differ too in moistness: earth is the driest, just as air is the wettest, and water comes in the middle. When I call something dry "deprived of water," and hence "heavy," this is because it is not extended. For when the original matter or *hyle* is not extended, it is dense,[35] and thus a thing dense in form and in weightiness. Consequently water is also midway in all these.

So it follows from this that all the stars are hot; for if all the stars have light, they all too combine.[36] By their nature the elements are all devoid of heat and light; and nothing can be less than what is nothing. Therefore all light is hot and
&85 combines,[37] and every star is hot because of that. But it is said that Saturn is cold only in comparison, because it does not combine so much as to assist generation in human beings, but hinders, in the way that tepid water mixed with hot water makes it less hot. That is why Saturn is more helpful than Jupiter, because crops require a more moderate heat, such as resides in Saturn, not in Jupiter. However, it is not moderated in the interest of human reproduction. All the stars, then, are hot, all the elements cold.[38] Once more: heaven is neither hot nor cold. Very many people are misled over the elements, on account of violent or imposed heat. For through this action of the stars, parts of the elements get to combining, and become potentially like hot pepper. But this is not an element, but a mixed body. A fire, too, which is kindled by the collision of stones is the heat of the stars in a rarefied body. So mixed things can be imbued with violent heat, some of them with corrupt heat, as in rotten items, others in potentiality, as especially in crops and seeds, others with imposed heat, as in the air in summertime, others with natural heat, as in animals. It is clear then why life on mountain ridges continues throughout the year, through the air's purity, but not life in Ethiopia, because of the heat, nor life in valleys, where the air is not simple, but can be hot

[34] J.R. Partington (*A History of Chemistry*, 4 vols. [London: Macmillan, 1961–1970], 2: 509) points out that later on, Robert Boyle (1627–1691) too considered that cold was a privation of motion and not a positive entity. Scaliger (*Exercitatio* 18, [87]) invited Cardano to take off his shoes and cap when the North Wind from the Rhaetic Alps is blowing, and see how cold and dry it is! Robert Boyle (*Sceptical Chymist*, 439; see also 96–102) was similarly impressed by cold: "And as for Cold itself, upon whose account they so despise the Earth and Water, if they please to read in the Voyages of our English and Dutch Navigators in *Nova Zembla* and other Northern Regions what stupendous Things may be effected by Cold, they would not perhaps think it so despicable."

[35] "multus"—but I cannot authenticate in *OLD* this meaning of "dense."

[36] "miscent"; the meaning is obscure—perhaps "combine heat with light."

[37] "miscet."

[38] Nenci (127 n. 21) points out that Cardano himself discussed Ptolemy's views on this issue in his own *Commentaria in Cl. Ptolemaei Pelusiensis IV de Astrorum iudiciis, aut, ut vulgo vocant, Quadripartitae Constructionis libros* (first published 1554).

and mixed. So in a [375]temperate region where the winds blow from the east, life is healthy and prolonged.[39]

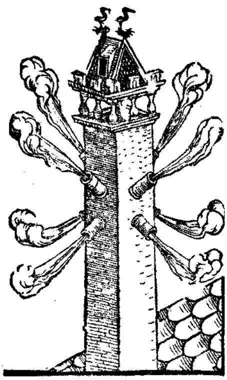
But more on this elsewhere. For the moment let it &86 suffice to know that there are to be only two qualities: the sky's heat, and the moisture of the elements. Dryness and cold are the deprivation of these. But we will pursue these later. To get back to our topic: what I call an element is not a very hot or cold thing, since such is hardly to be found. [A] But what I now term an element is what neither requires sustenance, nor is corrupted of itself, nor wanders about, but maintains a fixed position, as it has great mass, a mass according to nature, and it is ready for generation. And as none of these applied to fire, we will not call it an element at all. It moves about, unable to survive without nourishment, and burns the air beside it, and is called burning flame; a flame is nothing other than heated air. It is in unending motion and never settles down. For since fire is a very rarefied substance, and always burns what is subjected to it, it is also in incessant motion. Because of its subtlety, then, it can enter the tightest orifices, but because of its motion it splits up and parts things, and burns the parted things with huge heat and turns them into its own substance. It follows that a flame never stays the same, but with unending generation one follows upon another, and for that reason it always has to appear in motion. For when once in being, it invades the adjacent part of the air, and feeds upon its moisture, and in dying out &87 kindles another new flame. Thus when the pre-existent moisture is converted into flame, its size grown huge from this conversion, and could not propel the nourishment supplied to it because of its toughness, it has to rise vigorously upward, and is heated up to drive onward the flame already above it. This is why a flame generally proceeds upwards and strikes with a vigorous impact. But if timber situated above is ablaze, the flame has to proceed downward, for the same reason. So a flame does not always proceed upward, but normally does so because its nourishment lies below.

However, when it moves downward, it burns so much that if what is burning is moist, it suddenly quenches the dissolved fire. This is why the flame of a taper is spontaneously extinguished on being pointed downward. Timbers are different, because their moisture cannot be dissolved. They get extinguished too, but for another reason: because, as I said, the upper part of a flame is always being propelled upward by the lower part, the part which is nearer its nourishment. Hence the top part of a flame is put out in continuous sequence and turns into smoke; smoke is midway between flame and air, and consequently double. It is something that follows upon flame, and something rarefied and necessary. For every flame turns into smoke, but as smoke is very rarefied, it speedily passes on

[39] As Nenci points out (128 n. 23) the relation between climate and health was the topic of the Hippocratic treatise "Airs, Waters, Places" and continued a key issue in medical literature thereafter.

into the air, and consequently does not cause suffocation nor burn the eyes, but only heats and dries.

There is another smoke which precedes the creation of a flame, and is moister, and does burn the eyes and suffocate, &88 because it does not easily turn into air. It is usually the product of poor coal and rather moist timber. At its start, then, when a flame on tapers turned downward descends, this smoke meets the actual flame struggling upward, and rapidly stifles it. We have in fact stated that a huge amount of this is generated when by individual movements a flame, far distant from its nourishment and on its surface close to air, passes over into smoke; no wonder the smoke's abundance rapidly puts out a fire it meets. So the flame breaks everything up because of this rapid motion, not on account of the huge heat on its own. Still, this movement within the flame escapes us, because it goes on gradually. And the flame does not all go out at once, but only what is superficial; what is in the middle stays on till ultimately it reaches contact with air, otherwise it would not be in the midst of the flame.[40] But the smoke is carried backwards at times, either through impact, or its being repelled, or being barred. Impact occurs either on account of abundance or speed of movement. So green wood and abundance of flame fill bedrooms with smoke. Winds too push back smoke, and a narrow chimney bars its exit, especially if the chimney is narrower at its bottom so as not to accommodate the smoke. The principal cause is from winds, since smoke always rises higher both because of the impact acquired from the flame, and because of its lightness. Where it &89 encounters winds, particularly where a stock of green wood is in use, it falls back, and a chimney that has openings to four quarters is obstructed by every wind, being open in all directions. We have devised a rational remedy. In the four quarters, east, west, south and north, instal paired pottery channels facing them, in such a way that one leads upwards and &90 the other downwards; it is impossible for eight winds to blow from the four main regions of heaven, four inclining downwards and four upwards. Unless that occurs, the smoke can hardly be driven backwards, a conclusion confirmed precisely also by trial. Wideness of the outlets at the bottom is of considerable help. Also, the more secure channels are usually those tilted downwards only. But safer than all is one enclosed in a sheath that is not attached to the roof below.[41]



There are then three things required for a fire to burn: fuel, movement, and that it should work its way in. In a flame, movement is the greater and the

[40] Material from here to the end of this paragraph first appears in 1554.

[41] Nenci (132 n. 28) cites here the work of Leon Battista Alberti (1st ed. 1485), but I cannot identify there the "four direction" pattern of Cardano's description, in which he presumably took pride.

more obvious. Consequently too the entrance that follows upon the movement is greater, and it is very evident why the flame is more lively than the rest of the fire. And consequently, tapers burn while the flame thrives so long as fuel is available; when the flame stops, they are totally extinguished of themselves in a moment. But since the flame consumes [376]a good deal of fuel, that often reduces its duration during frosts. This however is not through the flame's own deserts,[42] but because the fuel is used up more quickly.

For these reasons, long-lasting flames are generated from fatty moistness, and enormous ones from rarefied dry substance, because flame follows quickly upon flame in rarefied dry substance, and hence grows to huge bulk. But if both these are combined, both dry rarefied substance &91 and some fatty very moist stuff, as in bitumen, then the largest and most long-lasting flames are evoked. This makes it clear why water poured over burning bitumen evokes larger flames,[43] a fact also recounted by Georgius Agricola, a memorable man of our time, that in Iceland there is evidently a mountain named Hecla,[44] from which fire is sent forth that is quenched by dry things but nourished by water. This, people say, is almost a general feature of all more powerful flames.[45] This is also the reason why smiths regularly stimulate fires by sprinkling on water; when the fire has got hotter, it is stimulated by cold and nourished by moisture, both of which are present in water. For this reason too, a fire which is fanned with bellows while strong is not put out by a moderate amount of water, but gets more vigorous; bellows fan fires because they stimulate movement; hence because of the movement the fire's power gets in and devastates. Bellows are essential in dealing with metals, since these do not melt with a small fire, but do so with a strong one, though slowly, hence they are consumed before melting. But a fire fanned by bellows is set in motion and makes its way in, and melts metals. Hence there is significant benefit in a rapid conclusion, both because loss is less extensive, and a smaller part of the metal is burnt up. So bellows are most suitable for fanning a fire and for softening and melting.

Returning then to my topic: water usually stimulates powerful fires, since the &92 very moisture it exhales turns fatter and is not consumed by the surrounding smoke, but the fire itself is fuelled by all of it, and thus growing purer

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42 "Hoc non merito sui est,"

43 A similar observation was made by the Roman historian Livy (39. 13), about women who "rushed down to the Tiber with burning torches, plunged them into the water and drew them out again, the flame undiminished, as they were made of sulphur and pitch [similar to bitumen] mixed with lime."

44 Now spelled Hekla. It is 4920 m high.

45 Nenci (133 n. 29) provides the relevant text of Georgius Agricola, *De ortu et causis subterraneorum* (1546), which states that it is burning pitch ("bitumen") at Hecla in Iceland which gives forth fire that consumes water, but not tow ("stupa"), explaining this by saying that pitch is extinguished by dry things, but fed by water.

and accumulating, it springs more vigorously from the coldness. Hence too, fires exist which are stimulated and kindled by water. They consist of naval and Greek pitch,[46] sulphur, wine sediment which people call tartar, sarcocoll,[47] saltpetre,[48] and a type of bitumen which people call petroleum.[49] This is referred to by Marcus Gracchus.[50] Accordingly quicklime is added in double measure, and everything is mixed together with yolk of egg, and buried in horse dung. Another recipe: oil of sulphur, petroleum, oil of juniper, and saltpetre, equal parts of each; black pitch, goose and duck fat, dove dung, the liquor called liquid vernix,[51] and it is made up with linseed oil; once again, the same amount of each; five parts of

[46] Greek fire became a most important weapon to the Byzantines, and was used with success in their campaigns up to the 13th century. Its exact composition is still a mystery. Naphtha or petroleum is thought to have been the principal ingredient, probably with sulphur or pitch and other materials added. It is not clear, however, how it was ignited, but quicklime was probably used, mixed with the main ingredients at the last moment. Once lit, the substance was very difficult to extinguish, needing sand or vinegar to do so. The mixture was packed into siphons which were mounted in the bows of galleys. See J. Haldon, "'Greek Fire' Revisited: Recent and Current Research," in *Byzantine Style, Religion, and Civilization: In Honour of Sir Steven Runciman*, ed. E. Jeffreys (Cambridge: Cambridge University Press, 2006), 290–325.

[47] "A gum used for healing wounds etc., or the bush from which it comes" [*OLD*]. It is referred to by Pliny (*Nat. Hist.* 13, 20 §67 and 24, 78 §128), where he remarks that it is a tree and gum useful to painters and medical men, and resembling incense dust or powdered frankincense—sweet with a touch of harshness, and gummy. It checks fluxes, he says, and is used especially as an ointment for babies.

[48] "Halinitrum": this is identified as saltpetre by J. R. Partington (*History of Chemistry*, 2: 54 and 262, though on 24 it is nitre!), who points out that Georg Agricola (1494-1595) distinguished it from "nitrum," which is soda. Biringuccio (*Pirotechnia* 10. 1, trans. Smith and Gnudi, 405–9) gives full details of the preparation of saltpetre.

[49] Castelli gives "petrelaeon" as a fatty liquor which runs out of rocks, white, or in some parts of Italy red.

[50] Ferdinand Hoefer (*Histoire de la chimie*, 2 vols. [Paris: Hachette, 1842–1843], 1: 284–89) transcribed and translated the *Liber ignium ad comburendos hostes* attributed to Marcus Graecus from a MS in the Bibliothèque royale at Paris, observing (2: 101) Cardano's error in writing "Gracchus" here. Hoefer notes that Mesue cited Marcus Graecus in the 11th century, and suggests hesitantly that Marcus Graecus might be dated to the 8th century A.D. The work gives various recipes, and warns of the danger of explosion if they are prepared indoors. The object of Marcus's preparations was to incinerate the enemy rather than to blow him to pieces.

[51] Although "vernix caseosa" is the normal term since about 1846 for the greasy covering enclosing a newborn baby, the word "vernix" is absent from *OLD*, but *OED* under the word "varnish" traces it to medieval Latin, and DuCange (8: 284b) offers "vernicium" as equivalent to "liquata juniperi lacryma" and cites "vernix" from an undated MS in the Bibliothèque nationale, without assigning a meaning to it. Castelli offers vernisium = vernix = sandaraca; same as juniper gum, it seems, and no reference whatever

asphalt; extract with boiling water, and bury in horse dung. Yet another recipe: of liquid vernix, of oil of sulphur and juniper, and of the oil made from flax seed, and of petroleum, and of exudation of larch tree, equal parts of each, of boiling water three and a half, then of saltpetre and dry laurel wood powdered, as much as required so that all these mixed together take on the consistency of mud. Enclose everything in a glass vase and bury it for three months in horse dung. If therefore balls made from these stick to pieces of wood, they will take fire of themselves during &93 showers; but this does not always happen. What however always happens is that once kindled, the fire is not quenched by any water.[52]

A powder which takes fire very readily, with a flame which is vigorously consuming, is made from gunpowder[53] and a third part of sulphur and Greek pitch. In addition, we have written more in those books of ours *De Rerum Varietate*, books which include a rich discussion of all the matters which receive rational explanation here.[54] The way in which these fires are not put out by water is readily clear in view of the fact that they evoke a motion so powerful that flame acts on flame as bellows do. So this is why it is easy to quench a little flame, but very hard to quench a big one—harder than a small one, not only because it is bigger, but because it evokes a powerful motion by which the flame is cherished, as I said. The size of the motion and of the flame compels people to keep far away, and hence help is not available to start with, and then as the smoke

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to vernix caseosa. Sandaraca according to *OLD* is either arsenic disulphide = realgar, or "bee-bread"; both meanings cited from Pliny.

[52] Recipes similar to those above, but not identical, are found in Biringuccio's *Pirotechnia*, Book 10, cap. 9.

[53] "Pulvis pyrius": Castelli states that this is a powder used for firearms and explosive weapons, made from nitre, sulphur, and charcoal; the reference given there is to Andreas Libavius (c. 1540–1616), German chemist, physician, and alchemist who made important chemical discoveries but is most noted as the author of the first modern chemistry textbook. He was professor of history and poetry at the University of Jena from 1586 to 1591and then became town physician and inspector of the Gymnasium at Rothenburg. In 1605 he established the Gymnasium Casimirianum at Coburg.

Of his numerous works, all of which were noted for clear, unambiguous writing, the most important was *Alchymia* (1606; "Alchemy"), a work that established the tradition for 17th-century French chemistry textbooks. Although he was a firm believer in the transmutation of base metals into gold, Libavius was renowned for his vitriolic attacks against the mysticism and secretiveness of his fellow alchemists. Libavius pioneered in the analytic approach to chemistry. Among his discoveries were methods for the preparation of ammonium sulfate, antimony sulfide, hydrochloric acid, and tin tetrachloride (*Encyclopedia Britannica*).

[54] This is Cardano's own work, completed in 1553 and first published at Basle in 1557; its twelfth book is entitled *De artificiis subtilioribus* (see Maclean, *De libris propriis*, M104 [94]). Nenci cites this work, book 10 (*De ignis artificiis*), chap. 49 (*Ignes vires et alimenta*) as including such material.

piles up, desperation sets in. In these situations only three resources remain: to remove inflammable matter, or to build up a wall of stones and project stones onto the fire, the way that some friends of ours saved their house close by from a fire. Or the way we use when woods or crops are on fire, by setting light to the part towards which the fire is making. For with the quenching of the fire, or even before its &94 quenching, by removing much of the matter we preserve the rest—a dangerous manoeuvre, but one that proved valuable. Our woods in the estate at Novarium[55] were preserved by this sort of resource, one not much different from the way the owner of the place often saved himself from danger.

Then there are places rich in bitumen or sulphur which take fire of themselves, and are barely quenched by water. The blaze at Mount Etna in Sicily is very celebrated. There are two craters: the lower one narrow, shaped like a well, with a narrow stony lip surrounding it; the upper one lies a slingshot from the bottom one, they say, and is four stades[56] in circumference. It ejects ash to a distance of a hundred miles all round,[57] blotting everything out in utter fog for a couple of days, as Pliny too confirms.[58] But in our own time it seems subdued. Yet at Puteoli (I hear it lies twenty miles from Naples),[59] shortly before we were writing this, great destruction followed upon a fire. These fires occur, therefore, where sulphur or bitumen is created, and especially near the sea, since bitumen and sulphur get kindling from marine debris and heat.

We shall turn next to how the matter is kindled, once it is ready. A fire which lies low from time to time and is in evidence only at night, as we have seen at Mugellano in the Apennines,[60] does no harm to trees nor even to herbs. There are two sorts: one really is &95 fire, but fire from vapours, which brings disaster with the passage of time, since that means matter becoming available. The other is entirely harmless, and is not really fire, but like decaying timber means [377]fire at night with its glitter alone, but no heat. Of practically the same sort

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[55] Novaria was in Piedmont in Italy; the word was also used of the river Agunia, a tributary of the Po.

[56] In classical times this corresponded to 740 metres [*OLD*]. I have here restored the punctuation of 1550, ". . . quatuor habens in ambitu stadia, ad centum M. passuum cineres . . ." and not that of 1560, which removes the comma and inserts a colon after "passuum."

[57] On the length of a mile, see note in Book I at 34 (1560).

[58] Pliny, *Nat. Hist.* 3. 88 runs: ". . . and Mount Etna with its wonderful displays of fire at night: the circuit of its crater measures 2½ miles; the hot ashes reach as far as Taormina and Catania, and the noise to Madonia and Monte di Mele." And II. 234: ". . . Etna, which is so hot that it belches out sands in a ball of flame over a space of 50 to 100 miles at a time."

[59] Puteoli (modern Pozzuoli) is 12 km (about 7 miles) north of Naples.

[60] Mugello (*sic*) is a district in the Apennine mountains in Tuscany.

of true fire is the star of Helen[61] round the mast of a ship, which on falling down melts even bronze vessels, a sure herald of a sinking, because it appears only in severe storms, and the vapour cannot be gathered together on a ship and take fire at the same time except with a powerful wind and great force of gales. Thus it also augurs imminent destruction. And from another point of view, the divine powers of Castor and Pollux in the past gave rise to such lights,[62] and now the same is true of Saints Peter and Nicholas, or rather their twin lights.[63] At times they are triple in the Ocean, indeed more commonly so than twin, because of the greater impact. People call them then the lights of Saint Nicholas, of Helen, and of Clara, the meaning being derived from the brightness in ancient superstition of the star of Helen, and because Nicholas is regarded as the patron of mariners in some accounts.[64] In the Mediterranean Sea there are only two, and usually on ropes, and jumping from one to another with a noise like birds, and they indicate the end of a storm, and even safety. There are indeed vapours clinging to ropes which with the passage of time and as they pass from one to another, exhibit the appearance of a &96 lit taper. Indications of safety are that they are small, not at all sluggish, they unite into one, and individual ones are soon over. Though they present a deceptive appearance of jumping, those that are more numerous usually

[61] Now known as St Elmo's Fire. Pliny mentions it (*Nat. Hist.* 2. 37. 101), remarking: "I have seen a radiance of star-like appearance clinging to the javelins of soldiers on sentry duty at night in front of the rampart; and on a voyage stars alight on the yards and other parts of the ship, with a sound resembling a voice, hopping from perch to perch in the manner of birds. These when they come singly are disastrously heavy and wreck ships, and if they fall into the hold, burn them up. If there are two of them, they denote safety and portend a successful voyage; and their approach is said to put to flight the terrible star called Helena; for this reason they are called Castor and Pollux, and people pray to them as gods for aid at sea. They also shine round men's heads at evening time; this is a great portent. All these things admit of no certain explanation; they are hidden away in the grandeur of nature." [Loeb translation] *Encyclopedia Britannica* describes their origin as atmospheric electrical discharge from pointed objects such as ships' masts during stormy weather, and (perhaps unaware of Pliny's reference) traces the name to Saint Erasmus, a patron saint of sailors, and mentions that sailors regard the phenomenon as of good omen and as indicating the saint's protection.

[62] See n. 61 above. Castor and Pollux were the Dioscuri, remarkable in Greek antiquity for their role as both gods and heroes, and in Homer's *Iliad* they were the brothers of Helen who was daughter of Tyndareos. They were revered for appearing in storms and at crises to provide assistance, in Greek legend and later in early Roman history. See Brumble, *Myths*, 65–66.

[63] About two and a half sentences opening here first appear in 1554.

[64] Nenci (138 n. 38) identifies a source here: Antonio Pigafetta, *Viaggio atorno il mondo*, in G.B. Ramusio, *Delle navigationi et viaggi*, 1st ed. 1550; in Venice edition of 1588, 353a and elsewhere.

amount to two, since as time goes by, many go on to present the appearance of a single more prolonged one.

So far, we have spoken about fire, and meantime added the usefulness of bellows. But it seems right to add also the basis of the motion: in fact, as we said, nothing develops remarkable about a fire which is not assisted by bellows. Bellows should be double, whether there are two or four or more, so that there is never a gap in their operation. Their motion is alternated, and is clearly a mixed one, derived from a violent one that opens them and makes them draw in air, and a natural one in which they collapse of themselves and expel the air taken in. It is evident that the faster the expulsion, the more vigorously the fire is fanned. This is why people load them with weights. But heavy items are not readily or quickly lifted up; this is why their apparatus needs rotation by great wheels and the powerful impact of water. These reasons indicate that even when very cold, ice cannot do as much damage as fire does by its heat. For just as fire makes its way by its motion into everything and disperses it by its entry before burning it up, in the same way ice constitutes a close-knit substance by a sort of inaction, the result being that it cannot make its way completely into &97 anything; experience demonstrates that ice is no less cold than fire is hot. For if you place ice for a while on burning wood or ingot,[65] the ice will not be dissolved faster than the fire is entirely quenched;[66] through its motion and rarefied nature, fire penetrates more and destroys and consumes more easily than ice, which shows that penetration and subtlety are the reasons for these remarkable effects, because things that are impenetrable (such as gold and diamond) are not consumed nor burnt up by fire, and really cannot be described as fiery at all. Thus ice is more resistant, through its density and inaction, and persists longer. For fire is always coming into being, while ice stays the same, and sometimes lasts for many years on the cold mountains below the Bear,[67] just as snow does. Therefore ice and fire are fundamentally contraries; fire is very hot, very rarefied, of very rapid motion, and encroaches on everything quickly and persists only for a moment; ice is very cold, and very compact, entirely inactive, slow to advance, and extremely long-lasting.

Thus the answer to a major question now emerges from this: the question whether this fire of ours is substance or accident. If it were actually a substance,

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[65] "later"; normally meant a brick in classical Latin, but could mean a bar or block of metal, and since here it is inflammable, presumably it means an ingot greatly heated.

[66] In the Galenic tradition, the assessment of temperature was a task for which only the human hand, when of a medium temperament, could be used; on this see Galen, *On My Own Opinions (De Propriis Placitis)*, ed., trans., and comm. Vivian Nutton (Berlin: Akademie Verlag, 1999; CMG V 3.2), 154–55. The thermometer, for which Sanctorius (1561–1630) is usually given the main credit, was not yet available in Cardano's time, but he is here proposing a species of quantitative measurement.

[67] There are two constellations named "Bear," both in the northern sky, but the Lesser Bear, *Ursa minor*, includes the (north) Pole Star and is therefore the more northerly.

the problem emerged of the way that in glowing iron there would be two substances at the same time, interpenetrating—that of fire and that of iron. Then suppose one—for instance the iron &98 substance—is dispersed, while it acquires fire corruption will occur, and while the fire is being quenched generation will be said to occur, which is ludicrous. But if you say that when an ingot[68] is burning, only the air inside is on fire, the substance of wood would not dissolve into ashes, nor would iron turn out much the worse. Therefore the iron's own moisture burns while an iron ingot is kindled.

But if fire is entirely an accident,[69] how does it change the substance of timbers into ash, and consume iron and almost everything? And so, as I said, this fire is nothing but the utmost heat linked with dryness. Nor can it be called a substance, unless fire can be regarded as the actual thing that is burning, in the way that ice can be regarded as the thing frozen solid. Fire then is entirely an accident, and is the utmost heat linked with dryness, and always resides in a substance as the other accidentals do. It cannot then be an element, as we have already shown above. For if it were, it would constitute a natural principle, by some chance, and should be surrounded with uncertain fuel,[70] and further, on the same basis ice would be another element. But if fire is another element, it[71] is in fact as hot as this one, or hotter, so it will need fuel, since it will have to be fed. Where will the fuel come from for such a mass? But if it is less hot, the basis on which it was reckoned an element fails. Indeed fire was supposed to be an element for the reason that it was an extremely hot and dry &99 substance, possessing both of these qualities, or one or other at any rate in completion. But it will not possess them, since it is now accepted that this latter fire is much hotter, drier, more consuming and more penetrating that the other one.[72]

However, a clear solution appears for another point of uncertainty, that is, whether fire can be hotter than fire? It is agreed that fire does not get hotter because of the matter alone, in the way that the fire in iron is hotter than that in a stake, and the fire in oak timbers is hotter than that in willow timbers; but just as in ice some is hardly solidified, some is hard, and some very hard, so some fire hardly is fire, as when iron begins to glow, some fire is more glowing, and some is dazzling. For as it is an accident, it can increase or diminish. So one fire is more powerful than another in six[73] ways: in nature, as we have said, since it consumes

[68] See n. 65 above.

[69] In the philosophical sense.

[70] "ac pabulo incerto circumferri oporteret"—meaning unclear.

[71] "siquidem aequaliter calidus est ac hic aut magis, igitur et ille pabulo indigebit, quoniam pasci necesse erit;"—meaning unclear. N.B. "glacies" is feminine, "ignis" is masculine, so "glacies" cannot properly be identified with "hic" or "ille."

[72] The meaning is unclear here.

[73] Five are specified, not six. But in his attack on *De Subtilitate*, Scaliger (*Exercitatio* 12 [65]) adds "ultimus, si sit coactus: vt in calce"—"when it is concentrated, as in lime."

more and faster when hotter; in matter, as fire residing in iron is more powerful than fire in straw; in motion, since it is more [378]penetrating; in size, whether its own size, or its long duration (no one can really find this hard to grasp); finally, in obstruction to ventilation—sailors are aware of this, who put one cooking pot on top of another on a little hearth and make everything boil, thus paying regard to their poverty. But as I have said, a tiny fire must be ventilated a little, or its own smoke will choke it. This is why people who take account of expense &100 make small ovens of bronze like a cooking pot, fitted closely with bars of iron at the bottom, to let the ash fall out. The final way is when the fire is confined, and for that reason lime is kindled by water, because the heat picked up in a furnace and then lying low, being as I said of the kind of fire, is held inside by the coldness of a little water, and then through both movement and combination itself bursts out into fire.

The[74] best lime therefore is the lime that gives off the greatest noise when water is poured onto it, and takes fire, kindling the adjacent timber. It is usually of an ashy colour, because in white lime the fire has already been given off, because air has got in; the whiteness comes on with the required entry of air. Lime from the solider rocks is like this, because the harder the rocks have become, the more and the more long-lasting heat they retain.

Later on we will show how the heat is given off in things that burn, and how fire is kindled by movement and combination. But movement not only makes fire penetrate further, but also kindles the actual heat, and as I said, makes fire hotter than fire. Thus it is no wonder how so much power is present in a thunderbolt, and how that fire performs marvels, as if it were different in nature from other fires. For its speedy movement not only makes it more penetrating, but also much hotter than every other fire. And so by contact alone it kills all animals except human beings, and a human being hardly ever has the chance to escape.[75] &101

[74] This paragraph first appears in 1554.

[75] Pliny, *Nat. Hist.* 2: 145: "Man is the one creature that is not always killed when struck—all others are killed on the spot; nature doubtless bestows this honour on man because so many animals surpass him in strength. All things (when struck) fall in the opposite direction to the flash. A man does not die unless the force of the blow turns him right round ("homo nisi convertatur vi percussus non exspirat"; Nenci however [143 n. 45] reads, "Homo, nisi convertatur in percussas, non respirat."). Men struck from above collapse. A man struck while awake is found with his eyes shut; while asleep, with them open. It is not lawful to cremate a man who loses his life in this manner; religious tradition prescribes burial." Scaliger (*Exercitatio* 13 [70]) stumbles over Cardano's statement here, regarding it as barely logical to say that animals all die and human beings generally do, and quibbles by alleging a case in which a man on a horse was killed by lightning, but the horse survived. The matter of protection from lightning is also addressed in Book VII at 444 (1560).

But Johannes Maria Cardanus[76] did escape, and survived by a rare miracle. And what other fire is there that kills by contact alone? This is its special property, because it is the hottest of the hottest, and to coin a phrase, the "fire of fires." Consequently it makes a big difference whether it comes from far off and from on high, or from near by.[77] And so sometimes when purses are struck the money melts, which is neither fabulous nor marvellous.[78] For the damage it does is done either by its extent or by the time taken; when it is very slender, it does not split a purse; since it moves very fast, it does not adhere, and therefore does the purse no harm. Air teaches it to pass through, and not stick to the purse because of subtlety; air makes its way in when an empty purse is split, and fills it. This could not occur unless it made its way in through hidden passages, since its mouth is carefully closed off. A spark of fire and a part of a thunderbolt is much more rarefied than air itself, and after making its way in, it attaches itself to metal, and by that extraordinary power it has and by its impact it rapidly melts it.[79] Some people have deplorably referred to this quite outstanding power of heat and exceptional dryness as a rare property, and as occult through its rarity—although it is accepted as exceptional heat and as I said, "Fire of fires."[80] It should cause little astonishment that this fire, or any other, can kindle rocks. For iron that is not glowing &102 still sets fire to wood and makes it burn, and wood does the same to sulphur even though the wood is not burning, and sulphur to brandy.[81] In fact it overcomes what is more solid, because in potentiality it is more loose-knit. So in very solid matter, a rather intensely hot fire will be capable of kindling rocks.

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[76] This man is mentioned in a work on lightning, *De fulgure liber vnus,* which is included in Cardano's *Opera Omnia* (2. 721), where it is noted as remarkable that someone's outside might be affected by lightning but not his inside: ". . . vt nos vidimus in Io. Mana [or possibly "Maria"] Cardano, Braesma cognomine, qui a supercilio ictus vsque ad pollicem, cum iacuisset ternis horis, vt mortuus, et reuixit, et superuixit,"—"as we saw in the case of Iohannes Mana Cardano, with the surname Braesma, who was struck from an eyebrow to a thumb, and when he had lain as if dead for three hours, he returned to life and survived." But the man's relation to any other Cardano is not mentioned. I am indebted to Professor Ian Maclean for pointing out that Cardano attributed this work to his son Giovanni, who was executed, and that this attribution is plausible.

[77] Pliny, *Nat. Hist.* 2: 138: ". . . all those coming from the upper heaven deliver slanting blows, while these which they call earthly strike straight."

[78] Pliny, *Nat. Hist.* 2: 137: "Of thunderbolts themselves, several varieties are reported. Those that come with a dry flash do not cause a fire but an explosion. The smoky ones do not burn but blacken. There is a third sort, called 'bright thunderbolts,' of an extremely remarkable nature; this kind drains casks dry without damaging their lids and without leaving any other trace, and melts gold and silver and copper in their bags without singeing the bags at all, and even without melting the wax seal."

[79] Nenci (with refs.) points out that Albertus Magnus discussed these phenomena.

[80] "ignis ignium." The remainder of this paragraph first appears in 1554.

[81] "aqua vitae."

This escapes notice, though of great potential advantage in besieging cities. Fires of this sort ought necessarily to be combined with great movement, and as I said, in very solid matter.

But why does a thunderbolt not strike columns nor ships' hulls? It rarely strikes them, but this does happen; at Florence we have seen a column struck and damaged in the great hall, or rather in the perimeter of the great hall. However, this is uncommon, and does not greatly break the column, since the blow slips off because of the roundness.[82] For the same reason, it does not strike hulls, except occasionally, because it is denied passage more than five cubits[83] under the earth. The hull of a ship is low-lying, but its mast, which is often touched by lightning, is high. And so to conceal oneself in deep caves is a sure protection against lightning, safer even than to be crowned with laurel, or covered with the hide of a seal or an eagle, or to carry a hyacinth stone[84] (people say it is not touched by a thunderbolt).[85] Some people have written "fig tree" instead of "laurel"—that laurel suppresses epilepsy and demons, that is, the famous timid conviction.[86] But we will discuss hyacinth later on,[87] since the &103 authorities who make this statement are no lightweights.

The thunderbolt's power once used to amaze people, but has stopped doing so, with the effects and the plentiful supply of military artillery; it seems little less violent than the thunderbolt. We know not where a thunderbolt comes from, nor from how far away, nor how much weight it carries. And there are people too who assure us that only fire is present, with an impact, and no stone.[88] This only we know for sure, that whole towers are sometimes demolished by a single strike. From one tower of Cardan's (the only one left, but an ancient one)[89] a single lightning strike broke and destroyed more than twelve thousand bricks. But most of these devices propel 60 pounds of iron over a distance of five miles

[82] Lightning's predilection for sharp or protruding points is well known.

[83] On the length of a cubit, see n. in Book I above at 24 (1560).

[84] Probably a sapphire (*OLD*, citing Pliny, *Nat. Hist.* 37. 125).

[85] Pliny, *Nat. Hist.* 2: 146: "[Lightning] does not strike a laurel bush. It never penetrates more than five feet into the earth; consequently when in fear of lightning men think caves of greater depth are the safest, or else a tent made of the skin of the creatures called sea-calves, because that [animal] alone among marine animals lightning does not strike, just as it does not strike the eagle among birds; this is why the eagle is represented as armed with a thunderbolt as a weapon." However, Pliny does not mention the hyacinth in this context, here or elsewhere.

[86] What these final words mean is not clear; the original runs: "Quidam ficum pro lauro scripserunt; laurum cohibere comitiales et daemonas, id est, persuasionem illam meticulosam." The sentence first appears in 1554.

[87] 1550, 1554 and 1580 here include the statement that "But I have heard even of a laurel tree at Rome wounded by a thunderbolt a few years ago."

[88] "sunt etiam qui affirment solum ignem esse cum impetu, lapidem nullam."

[89] It is unclear what this was.

(an extraordinary assertion, if experience did not create confidence in it); they make walls shake, and they shatter cities with towers, and no power can stand up to such an evil. The lightest is made from manufactured Cyprus bronze, shaped like the channel of a trumpet.[90] They ought not to be narrower or wider at the bottom,[91] since wider ones are not tightly closed by the cannon ball, and so possess less impact. But if they are tightly closed, they risk bursting, because of the large charge of powder. And if the narrower ones are not made longer, they barely contain as much powder as is required. If they are longer at the bottom, they turn out shorter above, and thus lose a lot of power. But if the iron ball does not go down as far as it should, they[92] provide a weaker impact because of the empty space left, and they shake the weapon, and even &104 sometimes break it. Yet the technicians (to the great detriment of princes),[93] in case the most evident calculation is thought too ordinary, contrive certain measurements in some cases too tight at the bottom, and others wrong and too wide, though there is only one basis, making them equal everywhere, excellent and very safe.[94]

The relation of the cannon's weight to that of the ball is hundredfold, so that if the [379]ball it is to fire is 20 units in weight, the weapon will weigh 2000. The thickness[95] at the foot, where the powder is placed, is three quarters of the diameter of the cannon ball. The weight and the measurement can be increased with that of the weapon.[96] But reducing it is not permissible without risk of bursting. At the top the thickness of the weapon's lip is is not less than one third of the diameter of the ball.[97] The diameter of the bore, as I said, is equal to the ball's diameter, and the weight of gunpowder to the weight of the ball. But in smaller guns, the weight and thickness of the piece should have a larger relation to the ball, for safety's sake, and on the same basis the weight of powder should be less than that of the ball.

From this the reckoning is clear, how much space the bottom should enclose: that is, enough to contain powder equal in weight to the ball. The hole where fire is set is also to take up a part of the base; the weapon is not propelled back so

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90 "Levissima ex aere cyprio factitio tubae in modum canalis efficitur."—syntax unclear.

91 Than the cannon ball.

92 The powder, evidently.

93 For example, James II of Scotland was killed by the explosion of a cannon on a battlefield in 1460.

94 Biringuccio (*Pirotechnia*, Bk VI, cap. 6; trans. Smith and Gnudi, 240–43) offers comparable advice.

95 Of the wall, evidently.

96 "Licet autem et pondus et mensuram cum eo machinae augere"; syntax elastic.

97 Nenci's n. 51, at 147, confirms this and the previous statement about wall thickness from Vannoccio Biringuccio's *De la pirotechnia* (1540).

much, since fire is set only forward.[98] Hence it is possible to take a straighter aim[99] for the explosion, and more safely. For when they &105 recoil a great deal, small guns harm the soldiers who use them; if large guns are not confined, they produce unreliable shots, and weaken the carriages on which they are mounted. If they are made to stay still, they are at risk of breaking. So one predictor of breakage is violent recoil; another is not fitting the measurement, as when it has become smaller or tighter than it should, or is uneven or oblique, which is almost the worst thing. A third sign is when the actual matter has turned scaly, or not tenacious enough, or full of blisters, or it has blocked the touch hole.[100] A fourth sign is when it has accumulated verdigris, or is wet with water. When the solemn procession of Corpus Christi was going on at Pavia in the year 1546, five or six men who were following the procession were killed by the bursting of artillery. A fifth sign is if you have inserted too much powder, or thinner powder instead of thicker powder, because with the fire too much increased and encountering no delay in its emerging, the weapon bursts. Bursting also occurs when the ball is forced in too violently. When the weapon is already under suspicion, it helps to prevent bursting if it lies on the ground while it has to discharge the ball, since with that freedom it is propelled in the direction towards which the fire propels it; but then with a very unreliable impact and exit. For this reason people put large artillery on movable carriages in such a way that they are parallel to the the ground and to the horizon; in this way, when they have taken up the fire, they recoil straight back and safely.

&106 There is also another new kind of fiery artillery, a cubit[101] and a half long, and weighing 70 to 80 pounds.[102] The bore[103] takes a shot of the size of a small ball. While it is being cleared[104] with an iron rod, it is supported and held

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98 "prorsum."

99 "Collimo" is cited once in *OLD*, from Apuleius, with this meaning, and *L&S* says the word is a misprint for collineo—*first* conjugation, and rare except in Cic. = *aim.*

100 "rima."

101 Traditionally a cubit was the length of a human forearm, which suggests that this distance is about 60 cm.

102 In France, a pre-Revolution pound weighed about 490 grammes (see Thomson, *Annals of Philosophy* 1 [1813]: 452–57), and so if Cardano is using a similar unit, this piece weighed about 36 kg, or half a man's weight. The weight of a pound could be confusing to establish; in *De Vita Propria Liber* (trans. Stoner, 193), Cardano remarks that 110 pounds weight of "the larger unit" are equivalent to 259 of the Milanese scale.

This item of "fiery" artillery may have resembled a relatively lightweight tube of wood mentioned by Biringuccio (*Pirotechnia* X. 5 [427]), but the latter was evidently longer (3 *bracchia*, about 175 cm).

103 "canalis."

104 "exoneratur"—i.e. being cleared during casting, though the meaning "loaded" would seem much more appropriate than "unloaded." But Cardano may be referring to the *casting* of the gun; Biringuccio (*Pirotechnia*, VI. 6 [240–41]) describes and illustrates

by its tail; it is a burden and a weapon for a single man. But because of its thickness it is marvellously powerful, yet no less safe. There is another one, in which a roomy cavity is situated next to the touch-hole:[105] various cylinders are added to the cavity, all of the same size, and their bores fit the bores of the weapon in a straight line, so that by changing cylinders the weapon does not get hot. We have seen at Pavia these inventions of the Prince of Saxony. The larger ones are made, as I said, of bronze from Cyprus, but the safest ones are made of iron, as now are all the smaller ones; it is difficult to make the larger ones from iron, which is why most of them are made from bronze from Cyprus.[106] The smaller ones are shaped on a lathe, the larger ones by casting molten metal, and thereafter on the lathe too. Moulds for the shaping of the weapons[107] are usually made from three pieces, since it would be too difficult to do shaping from a single one, as even like that it would be heavy. One part is the tube, a second is the male piston, a third is the base.[108] The weapon itself usually consists of one piece. I have also seen one made of two pieces, and with one of them bound to the other from the bottom with a screw turned on a lathe. The material, as I said, is manufactured bronze from Cyprus. It is made from actual bronze, and approximately a seventh part of black lead, or white lead or brass.[109]

&107 But such a great impact depends on the gunpowder. This is made from three parts of saltpetre and two of willow charcoal and one of sulphur, and suits large weapons. But for medium ones, ten parts of saltpetre, three of willow charcoal, and two of sulphur. And for small ones, ten parts of saltpetre, and one each of charcoal of hazelnut wood without knots and of sulphur. This is to be ground up with a wooden pestle, after moistening with well water, to prevent it taking fire during grinding. Some people add vinegar, some add hot water and dry the

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iron bars essential for the strength of the core used for that purpose. Hence my translation: "cleared."

105 "foramen."

106 On the manufacture and materials of guns of various sizes, Biringuccio (*Pirotechnia*, Bk VI, cap. 3 [222–27]) offers detailed advice, as also on all aspects of gunnery with which Cardano here deals.

107 "machinae."

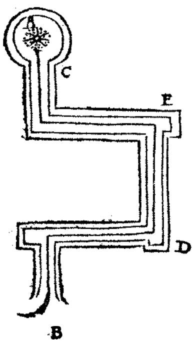
108 "sedes."

109 The "aurichalcum" here is the Greek ὀρείχαλκος or "mountain copper," sometimes spelled "orichalcum," which *OLD* regards as a form of brass, pointing out that Pliny supposed it occurred naturally; thus it could be regarded as a component of an alloy here. The translator of Biringuccio's *Pirotechnia* (Bk I, cap. 8 [70–76]) identifies it as "brass" and its preparation is there discussed in much detail. Some confusion arose about the spelling of the word because of a supposed association with "aurum," gold, noted in the eighth century A.D. by Paul the Deacon (Paulus Diaconus), in his abridgment of earlier work by Sextus Pompeius Festus. On Paul and Festus, see *Festi de verborum significatione cum Pauli epitome*, ed. W. M. Lindsay (Leipzig: Teubner, 1913), xix-xxi, 8.15. See also Book VI of the present work, at 430 (1560), for further discussion of this item.

product in the sun, but they do not grind it then, because it could easily take fire. In fact the whole worry is to get everything cleared like this of its earthy part, especially the saltpetre, so that it can all burn and no residue remain. Then, the aim is to reduce it to the finest particles, because like that the parts will best stick together. This will happen if it is frequently ground, moistened, and dried. Thirdly, when it has been brought to perfection, let it be dried in the sun, because putting it beside a fire is extremely dangerous.

Now let us look, then, into the cause of such a large effect. When this powder is placed in the weapon, and a ball is pushed in, and fire is applied externally at the bottom of the weapon, at once almost the whole takes fire, and strives to take up more than a hundred times the space. Indeed, &108 experience shows that a little powder on the palm of the hand will take up not less than a hundred times the space, since if the amount of a grain of millet of this powder is set alight, it fills the space of a nut with fire. Theory too shows this; for the rarefied and thin matter of fire is contained within wide limits, since earth and powder are solid and compact. And so, as the kindled powder is closely confined, it violently pushes the weapon outward in all directions, and finding no easy way out except where the ball was forcibly shut in, it forces it out with a huge effort, initially along the space of the bore, then it expels it outside with no loss of vigour, and as the impulse continues, it covers long intervals of ground, and overturns and demolishes everything in its way. It is likely too that this will be accompanied by a huge noise, since this fire emerges sufficiently and with a great impulse, and impinges abruptly on the air. The ball, too, emits a hissing sound as it rapidly splits the air. And then the saltpetre and every kind of salt emits a considerable noise, being placed of itself in liberated fire. Through these three causes (but especially the first), when the weapon is discharged a great crashing is set up, not much different from thunder. But if the powder does not take [380]fire all together, or is sluggish or impure or not properly finished, or has too little saltpetre, it emerges slowly, weakly, and with little noise. But if it is more rarefied than is proper, it ignites all at once and breaks the weapon. So it is apparent that as the speed of transition into fire &109 depends on the relation of the heat to the antagonism of the powder, an antagonism reduced when the powder is thinned out, this perfecting of the powder can proceed to infinity, so that it all ignites in a moment. And then, since it cannot find a rapid exit (all motion needs time), it smashes the weapon. It follows not only that a powder capable of smashing all weapons can be made, but when a more rarefied powder is inserted into the larger weapons, they will be destroyed. And on the other hand, with a thicker powder in slender small weapons, they will scarcely be able to expel the ball. So this relation lies within fixed and tight limits, and is linked to danger for those handling the weapons. But someone who makes and supplies the sort of powder appropriate for the type of weapons will handle them with safety and with maximum

impact. Further, the basis of mines is the same as that of these weapons,[110] but more remarkable. The creator of this horrible invention was Francesco Giorgio of Siena.[111] It was he who taught the Spaniards how to overthrow the Lucullan citadel close to Naples (now called Ovum) which the French were defending. This was after its sacred temple had been transported[112] into the sea from its mountain, along with the French who were inside. So when the citadel is situated mainly on the mountain and its site seems to make it beyond capture, they dig a kinked tunnel, four cubits[113] high and two &110 wide. The kinking does not make much difference, so long as you keep well away, but when you have reached the place you plan to undermine, a kinked tunnel is best, as at A, and the solid substance of the mound is here at the time, in case the power of the enclosed fire should vanish because of the open structure of the place. That place is therefore almost totally filled with gunpowder, and gunpowder of the most rarefied kind.[114] A cord is led from A right to the tunnel's mouth at B, the end close to A (where the powder is) being thick and wide like a tuft. The whole cord is boiled up with vinegar, sulphur, and saltpetre; then, covered with gunpowder, it is dried in the sun. After a further drying, very fine-ground gunpowder is scattered on it, and it is enclosed in a reed tube from A to B. Next, the mouth C and the passage up to D are closed with wedges and stones, so thoroughly that room is only left for the reed. So when the end of the cord at B is set alight, the fire penetrates very rapidly to A because of the gunpowder, and ignites &111 all the powder. The place is blocked with wedges and stones, which lack any way to get pushed out because of E not being in a straight line with A, and D not being in line with C, and B not being on the line ED. So when the mound is split, it overthrows everything above, demolishing the whole mass of the mound. Hence the path BA should not be short, and the site A should not be in a loose part of the mound, in case the fire explosion should burst out where there is a loose obstruction, and allow the region above to remain



[110] "machinarum."

[111] Francesco di Giorgio de Martina, born at Siena in 1439; for his extensive and distinguished career see *Dizionario Biografico*, 49: 753–65. This man is mentioned by Nenci, 156 n. 69, drawing on Biringuccio, as "Francescho di Giorgio Giorgi," an excellent engineer and architect of Siena.

[112] I.e. blown by a mine's explosion.

[113] Traditionally a cubit was the length of a human forearm, which suggests that this distance is about 60 cm.

[114] A much better figure of a mine is provided by Biringuccio (*Pirotechnia* X. 4 [424]), in which the gunpowder is seen stacked in neat barrels.

intact.[115] Thus the kinked nature of the tunnel is the cause of a marvel so great that even mountains can be overturned.

This[116] represents the old theory of mines, known to everyone at the time: in a comparable way, a very safe counter-measure is taken by digging out earth in the neighbourhood, so that by proceeding towards the mines we make the fire blow forth and nullify their assault. The sound of the miners tells us how to proceed straight towards the mines; it is picked up during the silence of the night, by brass vessels arranged all round inside against the rampart. Even though the enemy strive tirelessly to mask the sound by random[117] noises, if the besieged devote themselves to the task with precision, diligence, and skill, their assailants will suffer for it,[118] and their being discovered will do the plotters more harm than those plotted against. Perillus having an end like a bull.[119] An additional point is that very frequently—as the ranks of soldiers are overwhelmed by a dislodged mass of walls and &112 earth in the current siege of Cuneo,[120] through insufficiently experienced leadership—it is desirable to foresee which way and over what distance collapse will occur. In addition, in the books *De Aeternitatis arcanis*[121] it is laid down how these lessons should be taught.[122] But for anyone who still lacks a reason in mind for handing on and using material from these

115 Text present here only in 1550 and 1554 appears as Appendix 2 in Nenci, 315.

116 This paragraph first appears in 1560.

117 "inconditis."

118 "Faba in autorem cudetur." The phrase is a variant of Terence's "Istaec in me cudetur faba" [*Eunuchus* 381]—"That bean will be threshed against me," i.e. "I shall suffer for it."

119 Perillus created a brass bull for the tyrant Phalaris of Acragas (ca. 550 B.C.) in which the tyrant's victims could be roasted to death, but was himself made the first victim (Pliny, *Nat. Hist.* 34. 89; Loeb 9: 193); Ovid also tells the tale in his *Ars Amatoria*, 1. 653.

120 Nenci (157 n. 72) has identified this event as occurring in June 1557. Cuneo is about 94 km almost due south of Turin in northern Italy.

121 This work is Cardano's own, *On the Secrets of Eternity*, and was probably originally composed in 1538–1539 (Maclean, *De libris propriis*, M44). But since it was not published in printed form until the *Opera Omnia* of 1663, Maclean ("Interpretation of Natural Signs," 236) draws attention to its inaccessibility to the ordinary reader, as a circumstance that avoids "casting pearls before swine."

122 What might these lessons be? In Cardano's *De arcanis aeternitatis* (see n. 121 above) cap. 9 is entitled *De septem calamitatibus humani generis* (*Opera omnia* 10: 14–16), and there he does discuss disasters, starting from the proposition that the elements have disasters associated with them, for instance—plague with air, earthquake with earth, and conflagration with fire.

books, apart from the destruction of good men, it is an abominable[123] aim even to pass on published items of this sort, still less concealed ones.[124]

But departing from these matters, let us return again to the power of fire, from which substantial uncertainties arise—when we said that it was maintained by movement, why (someone will say) is frost better conserved below ashes than in the open, when ashes prevent all movement? This is an easy problem, having little to do with this book, which is concerned only with pursuing great, very hard, and very attractive matters. So later on I will avoid points such as this problem before us. It is then enough of a reply to it, that fire always has some movement, but frosts have quite a limited one, which even persists under ashes. Then when frosts are in the open, the air surrounding the fire breaks it up, because its preference is for breaking up rather than being broken up. And such a restricted movement cannot protect the fire, but it is safe from the air's onslaught when covered over with ash.[125] Thus the fire is preserved in three ways: either when it evokes movement from itself, as in tapers, and in general &113 when the flame protects itself by its own movement; or when it is promoted by movement from some other source, as happens when the wind blows, or with bellows, which is why big fires almost all arise while strong winds are blowing. Thirdly, when it is safe from the air, yet can still breathe, as occurs below ashes. It makes no difference whether the ashes are extraneous or (as occurs with certain timbers) it generates them around itself.

It is another problem, why we are more accustomed to call fire a substance than ice; no one called ice a substance, [381]but most people not only have called fire a substance, but have even considered it as one, although they are both accidents. The reason is self-evident. What we normally call accidents are things that are present without damage to the substrate, such as ice appears to be, since water, milk, and wine that have been frozen look the same when the freezing is reversed. But most things are spoilt by fire, and those that persist, such as stones and metals, look seriously damaged—apart from gold and silver, and a

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[123] "nepharii"—presumably "nefarii" is meant.

[124] The Latin here is very tortuous: "Sed cui nondum ratio ex libris illis tradendi utendique non in bonorum perniciem perspecta fuerit, nepharii propositi est etiam vulgata, nedum abdita, huius generis tradere." I do not know what Cardano means here.

[125] Nenci cites Aristotle, *De iuventute et senectute* 5. 470a7–16; this runs, "We can find an illustration of this in what occurs when coals are damped down. If they are covered continuously with a lid, which we call a choke, they are very soon quenched; but if one puts on and takes off the lid in quick alternation, they remain alight for a long time. And banking up a fire preserves it; for the air is not prevented from getting to it owing to the porous nature of the ashes, and the banking protects the fire from the surrounding air, so that it is not extinguished by the quantity of heat in it." Nenci also cites Aristotle's *De respiratione*, 17. 479a18–20, which just says that in old age the flame is tiny and extinguished by a small movement.

few jewels.[126] This is why people used to regard fire as something more than heat. But we have previously explained the reason for this difference.

There was another point open to uncertainty: fire used to appear as something separate from any kind of heat, but it is not, granted that it changes its colour, and readily generates fire like itself. But not every fire is bright; in fact fiery iron kindles sulphur and &114 burns it, from which it is clear that it has now taken on the form of fire, yet is not bright. Thus the fire given off by alcohol[127] is on a different basis, not just because of the rarefied nature of its substance,[128] but because it is less hot; hence even if it is consumed and shines, I would hesitate to say it should be called fire, as it does not burn up cloth to which it adheres and which is wet with the actual water.[129] Similarly, if it is distilled for some time and is much reduced, by a great miracle one's hand will burn, yet not feel it. And so if properly examined, when the heat has reached a certain level, it deserves to be called a fire. But this level is not a single one, but is the level when it can overcome the air. And when it has reached that point, it picks up as much brightness and light and strength as the heat itself does, and the fire itself increases. And it picks up a power proportionate to the compactness[130] of the substance in which it is; that is why glowing charcoal is hotter than a flame, so much so that gunpowder is ignited instantly by glowing charcoal, but with difficulty by a flame— people who are unaware of the cause are astonished at this as if it were important. Consequently, as I said from the start, fire is nothing other than very powerful heat linked with dryness. For fire cannot exist without dryness, otherwise boiling water could be fire. Then the essence of fire depends upon the very dryness, just as much as upon heat. For this reason we have been taught to &115 make torches out of any sort of wood, but if closer knit and more solid wood is used, the torches last longer. Suppose you split an oak shoot a cubit thick from top to bottom into very many pieces, for instance twelve or sixteen or more, in such a way that the bottom remains intact, and you dry it in an oven for two or three days. With the watery moisture excluded and the fatty part remaining, it burns like a pine-torch, and if it is as long as a man is high, a vigorous flame lasts

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[126] Books V to VII of the present work contain much more on the action of fire.

[127] "aqua ardens" means distilled spirit, but the translation used, while anachronistic, seems less likely to mislead than "spirit." See Partington, *History of Chemistry*, 2: 15, and the *Dictionary of Medieval Latin from British Sources*, 1: 113, which defines the phrase as "distilled fluid, spirit."

[128] Scaliger (*Exercitatio* 14 [73]) protests that this fire is extremely rarefied, and it is absurd to suggest that it is barely fire for that reason. Remarking that it still burns and even can create blisters after being immersed in snow, he is confirming that alcohol or a preparation of it is the meaning here of "aqua ardens." Later, he uses the phrase "aqua fervens" for boiling water.

[129] This "water" is probably the alcohol; see n. 127 above.

[130] "densitatem." This sentence first appears in 1560.

an hour and a half, with a very bright light. So, as I said before, a fire is as much extinguished by cold things as it is overwhelmed by wet things. The action of wet things springs from two causes: both because they are contraries, and because they prevent it from breathing and moving; the action of cold things is only from their being contraries. Then fire is extinguished by water on a threefold basis.[131] Now what remains in conclusion is for us to display the causes of fire's generation, which possess serious obscurity. So let us begin by examining the ways in which it comes about. It comes about by propagation, by antispasis,[132] by striking,[133] by friction, by decay, by combination;[134] the fire that is generated by concave mirrors or transparent spheres is clearly related to combination; the basis of combination is not obscure, since if you distribute ten coins to ten men, each will get one, but if you give them to five men, they will each get two. If then &116 heat which is distributed over a large interval is condensed into one, whatever was present in that large quantity is also present in that moderate one; therefore a great heat contained in a small space will bring about great effects, and for that reason will deserve to be called great, and hence "fire." This has actually been so clearly explained that there is no need of repetition. But the nature of antispasis[135] is reduced to combination. Antispasis[136] kindles for no other reason than because it concentrates into one; so it is known for this reason. And we have shown previously how it[137] can be generated by propagation. For each of the things that are constant and mortal by nature is suited for generating something like itself, and so there is nothing remarkable about fire being kindled by fire. But friction and striking[138] take their start from motion. Decay, however, is not enough to kindle fire, but is reinforced by other heat, either by motion, or by antispasis, and by combination. And so, if we have taught the way in which fire is kindled by motion, we shall demonstrate all the ways by which a fire can be kindled; also, that only three are genuine, combination, propagation, and motion, although far more seem to exist. Showing how fire is generated by motion is the same as showing how motion is the cause of heat; for if its motion is the cause of heat, it will also be the cause of heat's increase. And fire, as we said, is nothing but heat hugely increased. &117 Therefore the Aristotelians ask in what way motion is heating, and make numerous quibbles; in the end they return to the point that heat is the effect of motion, and this is as if they were to say, "We do not know."

[131] That is, by preventing fire from breathing and from moving, and by being its opposite.

[132] See n. 27 above.

[133] "percussio."

[134] "coitio."

[135] "Sed qui antispasi sit, ad coïtionem reducitur."

[136] See n. 27 above.

[137] Evidently fire, not antispasis.

[138] "percussio."

In fact, to establish a thing by means of the selfsame thing is sure evidence of an inexperienced quibbler. What is it that some people have said darkly and after their own fashion, that this heat is already in the air, but it is drawn down by motion to that form, and that this heat is the celebrated heat emanating from the stars? What a distinguished man![139] They do not assess the stars as hot, then they want this celebrated heat of the stars to be fire. But even if it is granted that stars, which they deny are hot, make heat, a further uncertainty emerges, about how motion is to increase that heat. For it is certain that heat previously taken up by the stars without motion is not yet fiery. Alexander[140] is right to take the view here that fire is not struck forth from stones, but the air held inside there is converted by sudden friction into fire. If however this is so, why is it not struck forth more from the most solid stones, like porphyry, and the hardest ones, than from the softer ones, such as crystal and chalcedony?[141] Again, why does fire not proceed more from two stones of the same kind, such as the crystalline ones, than from crystal and steel? Then why (the main point) do these sparks mostly sink downward in slow progress, as though they were heavy, if air alone is kindled? For pure fire either does &118 not descend, [382]or if it is made to do so by impact, it descends fast. Hence things that descend slowly do not consist of air alone. Alexander was therefore right to say that fire is not caught in a stone; for the fire would burn up the stone, and in turn the stone would burn up the hand of anyone who touched it, and would be easily kindled, and need fuel, and be easily emitted from two stones (chalcedonies, for instance) struck together, since friction would be enough to strike forth fire. None of these being true, it is utterly clear that fire is not held within a stone. But as I said, it is not generated from air, because stones, being harder, need greater striking force for fire to be generated. Thus if all that was needed was for air to be abruptly struck by the kind of blow that strikes fire from steel and crystal, fire could be generated from two pieces of steel. But it is not like that; as I said, harder things require more

[139] It is unclear why this word is not plural. Possibly Cardano has in mind a specific person, without naming him.

[140] This is Alexander of Aphrodisias, a Peripatetic philosopher who flourished early in the second century A.D. at Athens. For further details see for instance *OCD*. The passage is identified by Nenci (162 n. 81) as *Problemata* 1. 59. His source for the Latin translation is that of Gaza (Basle, 1537). I have consulted that of Angelo Poliziano (Basle, 1544; reprinted in London with the *Problemata* of Aristotle in 1583), which is to similar effect.

[141] Alexander (see n. 140 above) wrote in the same *Problema* that "some rocks consist of a loose-knit and light body; then the air is not so much thinned out by friction, not being influenced by any more vigorous blow, because of the body's lightness. It gives, and acquires a looser texture, and not being uniformly struck, cannot warm up. The phenomenon [of heating through friction] also occurs when pieces of wood are rubbed together."

vigorous blows, and create a more complete[142] and lively fire, the sort from which a spark sometimes lasts quite a while. Furthermore, there are some glassy and soft stones, which at the slightest blows or at a mere touch emit fire, but hardly lively fire. A sure indication that fire is generated from the substance of a stone is this, that it is never struck forth without the stone being rubbed. Air, too, as we said, bursts into flame, not into sparks. Furthermore, rotating millstones covered with water, not air, still emit fire; ordinary stones only do this from their corners.

&119 And so fire does not lurk within stones, nor is it generated when air is struck by air. But there is no sure view that a potentiality of fire exists within them; in fact they hardly take fire when thrown into a fire, and they are never ignited by cold, and when drunk down they produce vigorous chilling. This makes it obvious that fire is generated from friction of a stone when its substance has been reduced to its most minute parts, and the matter of one or the other is better suited to this. For the best suited sources are the purer ones and not too hard, and consisting of rarefied substance, such as chalcedony, crystals, and that sort of thing. Conversely, fragile things, or very hard ones, or those of thick substance, are hardly suited.[143] Similarly, lead is melted by the motion of an arrow, since the extremities, particularly those of the angles, which are very slender, get rubbed. The same thing happens in prolonged movement as does in numerous repeated small movements, such as when we rub a sword on a plank; but the sword because of its hardness resists a more vigorous friction that what is placed below it, so that the air compressed between, being attenuated itself, attenuates.[144]

But a return is needed to where I had digressed, about motion kindling heat, as upon this almost everything is seen to hang. So we never see fire kindled from water, and from air only with propagation, not with motion; and if one of the moist things is kindled by fire, such as oil and wine, it is ignited by fire, not by motion. Thus what is kindled by motion should be dry, not wet; still, even a moist thing &120 can be kindled by another fire. Then what is dry, and strongly so, is already half fire. In fact, as I said, a strong fire is heat and dryness. So what a dry thing needs is just to be warmed up; truly, the basis of part and whole is the same. For if it gets hot through a powerful motion, it will also get powerfully hot. Then when a dry thing is in collision with a motion, it has to end up rarefied and thinned out—but a thinned-out and dry substance is fiery. In fact, each single matter seizes on a form for itself subject to a definite quantity. This then is the one right way to put it: that the celebrated heat which originates from the varied[145] stars and is present linked to dry matter, while the matter is too much

142 "solidiorem."

143 The following two sentences first appear in 1560.

144 "hic eo vehementior attritio quo id quod suppositum est, etiam duritie sua resistit, ut aer in medio compressus dum attenuatur attenuat."—syntax and meaning obscure.

145 "mistis."

reduced by motion without resistance from moisture, because we have already supposed it dry, and is not much impaired through rarefaction by a previous form (for instance that of a stone) in case at the same time the qualities of a stone might be present but its substance be absent, they[146] take on the form of fire through heat's action.[147] Then this pattern[148] is, so to speak, contrary to combination;[149] in it heat is concentrated with the matter unchanged, but in the other situation the matter itself is rarefied when subjected to the same heat. That this is the cause is demonstrated by water being turned into air by motion, as anyone can see when waters fall with great impact;[150] indeed, substance thinned out and linked with moistness takes on the form of air.

But you will ask: in cold air and cold matter, in which cold is already triumphant, as in a stone, why does heat arise, though cold is the more powerful? My reply is, that &121 if cold is to be understood according to its action, it is nothing other than that celebrated heat in small quantity; what does not exist has no activities. This is why cold does not rise up, since it is only a privation, but heat does, which is on the other hand large in comparison to the scantiness of the substrate matter. An indication that cold is nothing at all except deprivation of heat is the rigor of tertian fevers, in which considerable cold is felt, although there is no cold matter, but a departure of heat. Therefore when small heat has been present in scanty matter, it is conserved. On the same basis, dryness is nothing but deprivation of moisture. Consequently the moistening of dry things is impossible, as there is no return from privation to the previous condition.[151] But moistening is harder, because the moist principle arises from an element, heat from heaven, which is always distributing it. Dry things are therefore restored only by the addition of matters. But chilling or drying more readily gives way[152] when these changes exist from an obstruction.[153] The ancients were right to regard ether and water[154] as the principle of natural things, though in the one, heat is supposed to be dominant, while in the other, moisture. They were more right to regard air as the principle of natural things, if it were hot and moist. No one regards earth in this light, because it is cold and dry. But preternaturally hot

[146] The substances, presumably.

[147] This monstrous sentence lacks both coherent syntax and clear sense, but is hard to translate with any greater clarity.

[148] "modus."

[149] "coitio."

[150] The spray arising from a waterfall, evidently.

[151] "habitus."

[152] "conceditur."

[153] Cardano soon, at 123 (1560), makes it plain that the source of the obstruction is matter.

[154] Scaliger (*Exercitatio* 19 [92]) protests that water is far too labile to be a principle of natural things; dryness is more apposite.

things are hard to cool, for heat preserves motion. So it is more difficult to cool things that are naturally like that, because their motion is perpetual. But in cold air a spark of fire is instantly extinguished, &122 unless protected. But air cannot prevent the generation of heat that occurs inside, since air is only outside.

But you will say once more: if cold is nothing in actuality except the deprivation of heat, how are cold things cooling, in the way that hot things are heating? Cold is always present with much matter; indeed nothing very thin can be cold. Much matter prevents heat making its way in and being in motion, and [383] hence is cooling in this way.[155] Thus what heats does its heating of itself; what cools does so only by accident.[156]

You may perhaps object: since we feel ourselves chilled by cold things just as rapidly as we feel heated by hot things, some kind[157] of cold seems to have been brought into action.[158] As in fact I said, cold is nothing but deprivation of heat; and things that are in motion and not stationary, like water and the air of strong winds, are cooled. Again, when something is chilled by contact, only its surface is chilled, the heat manifestly taking refuge inside. And this is why it is impossible for anything to be rapidly chilled; but even the parts furthest inside are chilled when the delay is prolonged.

And these are the real natural foundations of things, in which there is no repugnancy. The people who imagine these qualities as attached to substances, and that cold is some principle of nature, make their way into very knotty points, and cannot tell the &123 causes of things that come to notice, and are working to wrap everything up in silence and in words that are obscure and even ambiguous as well. Heat itself, then, is the special heavenly quality which stirs up these bodies, the quality that creates fire with the aid of motion. If it is overwhelmed and obstructed by matter, it generates cold. And anything that does not remain in the same state of motion turns out colder, as water and air do. And the temperament of the air is the result of the profusion of rays from the Sun, and from the stars too, which it receives and which heat it up. But earth, not being moved, cannot be as cold as water.

With these points made, points by which we will display a number of secrets of nature which have lain long hidden, let us return again to the account of fire. But it is as well to say something first about the subtlety of substances. Some then, such as air, are described as rarefied in themselves; some rarefied in

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[155] Scaliger (*Exercitatio* 19 [93]) protests that on considering the case of air, for instance, it is not *much* matter that obstructs the entry of heat, but *compact* matter. Much air, since air is rarefied, does not do so.

[156] In the philosophical sense.

[157] "species."

[158] "Repugnabis forsan, quoniam refrigerari sentimus nos, non aliter a frigidis, tum repente, ut a calidis califieri, ut producta frigoris quaedam species videatur."—syntax precarious.

quantity, like hairs; some so because they flow, like blood; some so because they can be divided into very tiny parts, like gold; others because they have several of these characteristics, like spirits, which are the instruments of our operations. And most things are made fine-grained by technical skill,[159] like lead, which is so much refined by technical skill that it is reduced to the powder from which clocks[160] are usually made; when molten it is rapidly rotated in a mortar, to convert it to powder when it cannot be held together. Though technical skill reduces timber or stone or metal to very fine particles, it still &124 does not mix or break down the substance, but only the quantity. If fire breaks things down, it separates them; if it mixes them, it does not break them down. Yes, by separating bulky things, it provides the semblance of an agent that breaks down. Only nature[161] can mix and break down a substance at the same time. Indeed, as I said, since I now mean by "subtle things" things that can be drawn out finely, and they have to be ductile or moist, and since fire dries, it cannot break things down without separating them. So it breaks things down, either by crushing dry things, as when it reduces sand to dust; or by liquefaction, as with metals; or by separating rarefied parts, as in the course of distillations. In fact, while it burns, since it crushes dry things and liquefies moist ones, it also breaks things down. In the course of distillations, however, it comes about that something is broken down and mixed with something else, when the distillation is done with moist heat, not with fire. Yes, heat does mix, and along with moistness it breaks things down. And this is what occurs when the containers are put into boiling water (what is called a "bain-Marie"). The sort of distillation next to this in excellence is that in horse dung; the reason is that the most valuable part in the waste from olives is drawn off as ashes, after the oil. For when the substance is hot and moist, it can preserve heat over many months, and for an interval of time longer than bunches of grapes can, in proportion as the substance of olives is more compact and fatty.

But none of these agents can melt metals—they require fire. But making a &125 distillation very hot by fire involves unsuiting it for mixture and true breaking down; distillation by ashes is broadly similar. For if you mix things distilled by fire with their sediment, in proportion to its mass the whole will get heavier than before, and drier too at the same time. So it is not really fire that breaks down, but nature itself, which concocts and mingles the whole of the substance. Hence everything comes together because of subtlety, and the mix becomes more compact, and yet made up of the finest particles. So in a natural coction, in order that the coction that is toughest for melting may also acquire

159 The rest of this sentence and the opening of the next one first appear in 1554.

160 Cardano may mean here the *weights* of clocks, which are discussed in Book I at 27 (1560).

161 The word seems here to indicate some kind of chemical process.

the power of fire, and that of a mild bath for breaking things down, the thickest parts are split up, a task beyond fire's power.[162]

But out of this a considerable uncertainty emerges: if fire heats and dries everything, all the waters that are the product of distillation ought to be hot and dry. And their substance is no obstacle, because it is watery; indeed, as it is like that, it is fiercely hot, and burning, and it notably heats and dries human bodies. Besides, all waters are cold and wet, when their substance prevails. But the reality is always neither of these; indeed, some of these waters are more like what they were extracted from, for instance in rose-like smell, taste, and strength. A pitcher of plantain water can arrest a flow of blood from any source. Lettuce water, cool though it may be, does not do the same. Someone recently struggling to improve his memory infused balm[163] for three days with white wine, and then gently &126 squeezed the wine out and gathered the water by distillation. By drinking it he thought he had recovered his memory. But when he was eating some hot liver, he almost completely destroyed his good health. Chemists call this ploy "fixing stars in the sky."

So the usual question is, do these waters retain their special powers? We once said, in dealing with the misuse of therapy, that they had no powers, being devoid of odour and taste.[164] Yes, wormwood water neither smells of wormwood nor is bitter; furthermore, it is surprisingly sweet. However, passing over rose water, alcohol[165] creates belief that there is power in waters. For if you say it is like that because of the fire, why is it that none of the others is like that?—this one is notably heating, it dries, it makes its way in, it smells sharp, it burns. And so it is beyond doubt that powers now reside in waters, but not in all waters, nor equal power in all. Indeed, anything that has a substance rarefied and linked to a cold substance gives forth a water not unlike itself, as a rose does. What has a rarefied and hot substance gives forth a similar one, but burning, as wine does, and some of the metals. What has a thick and hot substance gives forth a different and debased one, as wormwood does. What has a thick and cold substance gives forth a different but not a debased one, as a gourd does. Along this line of

[162] "Ergo in naturali concoctione, ut quae in liquando durissima, etiam vim ignis obtineat, et mollis balnei in attenuando, partes crassiores comminuuntur, quod ab igne impetrari non potest."—translation precarious.

[163] *Melissa officinalis*; the effect of this plant on brain function is even being investigated nowadays. I have not found in Dioscorides or elsewhere evidence that herbal therapy for memory has been explored in the past. Frances Yates (*Art of Memory*) does not mention such an approach. However, research at Newcastle-on-Tyne did in 2003 indicate changes in memory and accuracy of attention after administration of lemon balm; see http://nootropics.com/lemon-balm/index.html, accessed on 11 March 2011.

[164] In Cardano's *De malo recentiorum medicorum medendi usu libellus*, cap. 12, 21 (1536 ed.; Maclean, *De libris propriis*, M32), cited by Nenci (169 n. 89).

[165] "Ardens"; see n. 127 above.

thought you will readily learn the powers of waters [384]which can be extracted by a moderate fire, because those that need a powerful fire all are vigorously drying, and most of them also are warming.

&127 In that case a further uncertainty arises, whether it is feasible to make temperate water, which is called the Fifth Essence.[166] As I shall make clear, this will be the ether, that is, a highly rarefied mobile substance, one that holds on to a temperate (yet very plentiful) heat by its motion. It can thus preserve all its powers, and prolong life. For being very rarefied, it mingles with the primeval moisture, making its way into solids, and detaches the refuse which is contained in it. Because it possesses a great deal of heat, it ejects anything impure, and thus restores its natural heat. Old age is merely the diminution of the natural heat—it is diminished because movement is prevented, as I said in the case of fire; indeed, the relation of the latter to the former is similar. But movement is prevented because of the abundance of earth substance, since earth is alone in possessing very much matter and in altogether lacking movement. Hence that particular water, being of a temperate heat, will not distress the heart nor be damaging to the liver. And so it is the only one that can offer what I have mentioned.

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[166] This alchemical substance, also known as the "Quintessence," is discussed in Biringuccio's *Pirotechnia* (trans. Smith and Gnudi, 39); he does not believe in its existence, regarding such belief as credulity, and equates it with "Fifth Essence," "Philosopher's Stone," and "Potable Gold." Ulstadt however devotes the initial 90 pages of his *Coelum Philosophorum* to elaborate description of how to extract it from a whole range of sources, including human urine. Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 150 ff., discusses quintessence. See also n. 17 above. Philoponus dismissed it already in the sixth century.

People report that in the island Bonicca,[167] which is 1200 miles[168] away from Hispaniola[169] in the New World, there is a spring on a mountaintop which rejuvenates old men, but without altering their grey hair nor removing the wrinkles they have already developed. In addition to the prevalent rumour, a responsible witness is Peter Martyr d'Anghiera of Milan, in his &128 "*Decades*,"[170] from the private papers of a one-time King of the Spains, of the world new-found in his times. But Oviedo[171] persistently denies it. We have no doubt it is possible, but do not maintain it is true. Then it is the less credible because it is said to happen quickly and in a few days. But a man grows old through a long range of years, so he cannot be rejuvenated except over a range of years. So to test and check this is very difficult. In good air, the water ought to be excellent; and there is excellent

[167] The location of this island with its famous rejuvenating spring is unfortunately elusive. Peter Martyr d'Anghiera (Book 10 of his *Decade* 2; trans. Eden, 87) calls it "Boiuca or Agnaneo" and locates it 325 leagues from Hispaniola (Haiti + the Dominican Republic). He does not explicitly speak of the removal of grey hair and wrinkles, but only in a general way of physicians who with "certayne secreate medecines and dyet" could enable the "accidentes of age (as they caule them)" to be "longe hydden and deferred." Peter Martyr, also referred to in n. in Book VII at 491 (1560), was born near Anghiera (on Lake Maggiore in Italy, about 60 km NW of Milan) in 1457. He served as a diplomat at the Spanish court, and composed celebrated historical descriptions (1511–1525) of the voyages of Columbus and other events in the newly discovered Western world and elsewhere. He died at Granada in Spain in 1526. Other accounts of the spring and its location differed; details at http://www.tfn.net/springs/Springbook/FountainLegend.htm (accessed on 21 Aug. 2006) include: "Writers disagree somewhat as to the situation of this fountain. Hakluyt (Vol. V, 251) and Gomara (*Hist. de las Indias Occidentales*, Cap. XLV, pp 31, 35) locate it on the islands Boiuca or Agnaneo, 125 leagues north of Hispaniola. Some placed it on the island of Bimini—which, says Oviedo, is 40 leagues west of Bahama (Pt. I, lib. xix., cap. xv, quoted in Navarette)—a name sometimes applied to Florida itself, as on the chart of Cristobal de Topia given in the third volume of Navarette. Herrera, La Vega, Fontanedo, Barcia, Navarette, and most others agree in referring it to Florida. Fontenado confuses it with the river Jordan and the Espiritu Santo or Mississippi. Gomara . . . gives a unique interpretation to this myth and one quite in accordance with the Spanish character, namely, that it arose from the rare beauty of the women of that locality, which was so superlative that old men, gazing upon it, would feel themselves restored to the vigor of youth."

[168] On the length of a mile, see n. in Book I at 34 (1560).

[169] The "Spanish Island"; now Haiti and the Dominican Republic.

[170] The title of Peter Martyr's works.

[171] This is Gonzalo Hernández de Oviedo y Valdes (1478–1557), a Spanish explorer who wrote a very substantial history of the Indies, its first part being published in 1535 and a further part in 1557. Nenci (20) draws attention to his presenting the fruit of personal experience, unlike Petrus Martyr, who is also quoted by Cardano, and stayed in Spain! For details of Oviedo's account of longevity in the New World, see Nenci, 171 n. 94. The rest of this paragraph first appears in 1554.

air, as I said, on mountain ridges. But there many problems exist for human beings, since it is the experience of few of them to attain this relief from nature.

So to return to the point, and prevent its pursuit taking so long: when alcohol holds on to its rarefied state during the diurnal rotation, and has shed its heat and the peak of its taste and odour, it is ether. Initially, however, it has a smell. A fragrant[172] odour, indeed, is nothing but a sharp one when it has shown itself moderate. The evidence is that pepper is not fragrant, nor is ginger, because they are excessively sharp, but a small amount smells pleasant. But things that smell pleasant on the opposite basis—cinnamon, amomum,[173] crocus, cloves, lilies, musk—are moderately sharp. And if you apply a lot of one of these, such as pepper, to your nostrils, they smite the brain and do not seem to smell pleasant.[174] Garlic and leeks, which have a humour with something of rot in it, smell foul even though sharp, yet also because they are not moderate. So alcohol has to get fragrant if it has returned to temperament &129 without losing its rarefied state; and if it gets fragrant, it must be converted reciprocally into ether. A water to restore youth is also made with snake flesh,[175] and one is made with hellebore, of the sort I saw at my father's house. But these ravage bodies, and recover a rouged[176] picture of youth, but do not offer youth. Ether, however, offers real youth, since it keeps what it has for a long time, and enhances it. But not forever? No, but as long as there is nothing to stop it; yet much matter does stop it.

Can one turn the clock back with fire,[177] which is a very hot and more rarefied ether? Surely it is like that, since it is close to heaven, and hence very light; indeed, it holds on to its rarefied state, and through its rotation moderates the heat imposed by the stars. And in the same fashion this water,[178] brought to the utmost rarefaction by fire's heat, is cooled by the very movement and takes on a tempered condition. Consequently both this water and the ether are a sort of midway stage between mortal and immortal things. Indeed, since it[179] possesses a location and a tempered condition, as well as a substance close to heaven, it is incapable of degradation. But when it is propelled downward, it is cooled, and

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172 "fragro" normally refers to any smell, pleasant or unpleasant.

173 It is difficult to identify this spice in modern terms, and the works of Jacques André and *OLD* do not succeed in being specific.

174 Scaliger (*Exercitatio* 21 [98–99]) disputes the arguments here, relying on his own judgments of the sensations involved.

175 "Tyri carne": Castelli under Tyria offers: "Tyri enim voce omnes serpentes, et potissimum Viperae intelliguntur."—"By the word "Tyri" all snakes are meant, and particularly the vipers."

176 "fucatam."

177 This translation of the two words "Rursusne igne?" is speculative, but may be satisfactory nevertheless.

178 "haec aqua"; it is unclear what water is meant.

179 Evidently the ether.

thus over many centuries gets degraded. Consequently it is a sort of midway stage between the mortal and the immortal, a kind to which the Stoics believe the human soul belongs.

But because this ether is derived[180] from alcohol, since it is thinned out by heat, and is not constrained by movement, it turns out quite a lot more rarefied. And so each of them[181] is made on a similar basis. In this way &130 anything that is altered by the heat of fire takes on obvious hotness and dryness: for instance lime and ash. But these two differ, as the heat in lime is unlimited, but in ash it is all nearly used up already. This is why people who assemble cauterising medicaments from lime and ash look for the heat particularly from the lime, and for dryness from the ash. Those who extract the water with which metals are separated work in this way. It goes on thus: one part of saltpetre,[182] three parts of liquid alum, which is called "rochae,"[183] middle part of sand, items carefully dried and purefied are distilled with fire in glass vessels. What first flows out is collected separately, when the vessel's surface finally looks saffron-coloured. On increasing the fires, another fraction makes its appearance, which is mostly included[184] in the previous one. However, if you receive it in spring water, it is still so bitter that it nevertheless dissolves silver and separates it from gold. It is separated thus: collect a moderate part of the extracted water, and put onto it an obol's weight of the purest silver (that is, twelve grains);[185] let this stay on ashes long enough for the silver to dissolve. This will throw down onto the bottom of the vessel a sediment[186] like thin lime, and when it has been removed, add the rest of the purer water to the whole of the water on which you had drawn already. This will throw down to the bottom a sediment on a similar pattern, like the previous one. When that is removed, you will have all the water extremely pure, and more effective for dissolving &131 silver and the other metals (except gold). Since it readily evaporates, it is kept in a glass vessel carefully sealed. To assay the extent of its powers, let well water be taken up, as I said, and, even without fire, reduce silver into water for twenty-four hours, and with the moderate heat of ashes for two or three

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180 "elaboratur."

181 "utrumque"— but it is unclear why this neuter form is used, since neither ether nor water is neuter.

182 "halinitron": see n. 48 above.

183 Castelli gives under the word *rochum* "Epitheton *aluminis*, et quidem quod *Rupeum* vocatur. An a Gallico *roch*, quod *rupem* significat. Paracelsus simpliciter *rochum* vocavit (refs. given). In officiniis vocatur *Alumen rochae*." Scaliger protests (*Exercitatio* 104(6) [385]) that alum is Alum *Rochae*, which he asserts means "*rock* alum," so it cannot be treated as a liquid. He took the word "Rocha" as Greek ("Quae Graeca vox maximae Europae seruit parti ad rupem significandum"), but it is not classical Greek.

184 "excipitur."

185 Information on *French* pre-Revolution units indicates that this weight would be about two thirds of a gramme if the grains had been French ones.

186 "purgamenta."

hours; everyone would assign to these final vapours, and to the water into which they are turned out, a remarkable—indeed, unbelievable—power.[187]

Of the same kind is what happens to the salts sal ammoniac and nitre and then to [385]copperas[188] and liquid alum, equal parts, finally adding a quarter part of verdigris. When this is prepared in the same fashion, it has no mercy even on stones. But if you have added some of the Ostracitis[189] called Smiris[190] with which people polish gems, you will obtain a more plentiful and better water, because it is not burned. So with these findings from experience, let us see why this water turns out so potent; an obvious trial tells us that the drier part, thinned out by the fire's force, accepts the fiery corrosive power.

But why does the water of separation not burn, being very hot?[191] Because what is very hot is hotter and thinner and less dry, so that it can burn and can

[187] "Vires autem aestimanti quantas habeat, quae excepta (ut dixi) aqua putei, etiam sine igne in horis 24 argentum in aquam redigat, modico autem cinerum calore in duabus aut tribus horis, non est qui miram vim vaporibus illis extremis, ac aquae in quam vertuntur, imo incredibilem non tribuat." Translation speculative here.

[188] "calchantum"; Dioscorides (Wellmann ed. V. 98, Sprengel ed. V. 114) refers to "chalcanthos" as a bluish mineral, good against flatworms and other conditions; Galen discusses its virtues in his *De Simplicium Medicamentorum Facultatibus* (IX. 34; K. XII. 199) and in the Kühn edition the original Greek word is translated as "atramentum sutorium"—"tailors' blacking." Crosland (*Historical Studies in the Language of Chemistry*, 72) identified this as copper sulphate, which is blue but can blacken leather. A website http://www.uni-mannheim.de/mateo/camenahist/besold16/besoldusnatura.html defines calchantum as "couperose, flos vel rosa cupri, Kupfferivusser," and so I have used the translation, "copperas" ("a name formerly applied to copper and other sulphates, now only to ferrous sulphate. Derived perhaps from cupri rosa or aqua cuprosa": *Chambers' Dictionary*). On the other hand, Nenci (490 n. 115) cites Antonius Musa Brasavola (1500–1555: physician at Ferrara and later for Popes Paul III, Leo X, Clement VII and Julius III; also for Francis I of France and Henry VIII of England, also very active in medical botany), who noted the uncertain meaning of "chalcanthum"; Brasavola wrote that his "vitriolum" might be called "colchotar" by some people, which was better named "chalcanthum" and was very caustic, and indeed toxic if inhaled. Brasavola spells calchantum (copperas) "colchotar" or "chalcanthum"—it is pretty consistently spelled "calchantum" in *De Subtilitate*.

[189] Castelli says this is a very hard stone like a shell, created in the bottom of furnaces out of thick matter.

[190] Emery, as Adams on Paulus Aegineta (3: 221, 226) remarks; he also mentions that Dioscorides recommended it for looseness of the gums (he does, at V. 147 [Wellmann] and says it is good for polishing tiles). Castelli describes this as a very hard rough stone, used by the carvers of rings and other craftsmen to split glass and other stones. Galen (*De Simplicium Medicamentorum Facultatibus*, 9. 34; K. 12. 199) mentions its use for dealing with bladder stones, remarking that it is very "abstergent" (ῥυπτική). In Book VII, at 480 and 505 (1560), Cardano supplies much more about smiris.

[191] On *aqua ardens*, see n. 127 above.

warm things notably, yet not corrode. But this can corrode but not burn, and can only warm a little. So on the same basis, the oil extracted from copperas[192] by fire's power is very sharp, since it turns the driest part into &132 moisture,[193] and stings the tongue like fire. Hence it is agreed that on this basis also a water can be made which when applied to a bladder stone by catheter breaks it up at once. For since two properties are needed—one to grind down the stone, and one to be harmless to the bladder—the technique[194] and the matter will provide the first. For we will extract the ultimate vapours from scorpion ash, or Macedonian parsley,[195] or tecolith,[196] or the stones of crabs. Indeed, a water could be made thus which would pulverize even porphyry.

What is more, it offers harmlessness, if the matter from which the water is extracted has all been free of saltness. It will be appropriate to extract the water, not from some kind of salt or alum or copperas or sediment of wine, but from one of the things we have recently recovered. Careful experience[197] is always needed in the confirmation of a subtle theory, so that we can turn to human use the points we have so subtly explored, securely confirmed by experience. Personally, I know that pigeon dung and pellitory,[198] the former or the latter extracted into water, can break up the hardest bladder stones. What this is, and what it is going to do, and without harm too, needs clarification by experience. For boar's blood, and hare skin, and glass are much endorsed by theory—yet perhaps none of these separately, but some of them combined together and in a definite measure. Such a thing surely needs to be &133 metallic, or altered towards the nature of metal. I once heard that someone from Genoa had found it, but it was lost again at his death; he had not wanted to make it known to anyone. What is quite certain is that it can be found, and that this is its technique.[199] But there is doubt whether rarefied things are sharper, and whether they are more corrosive.

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[192] "calchantum."

[193] "humor."

[194] "modus."

[195] This must be the meaning of "petrosilium" here; the Greek word πετροσέλινον = parsley, and Durling refers to the Macedonian sort being mentioned in Galen in several places.

[196] This word is in Pliny (*Nat. Hist.* 36. 143; 37. 184) (*OLD*). Castelli under *Judaicus*, *Judaeus*, offers a white stone like an acorn found in Syria, supposed to melt bladder stones, which is what the Greek τηκόλιθος means (τήκω = melt.). And Galen (*De Simplicium Medicamentorum Facultatibus*, 9. 34; K. 12. 199) refers to it, as does Paulus Aegineta (lib. 7 sect. 3; trans. Adams, 3: 221), with the same general meaning. Nenci (656) points out that Agricola (*De natura fossilium* 5. 260–261) mentions that it gets its name because when swallowed with some wine, it breaks up renal stones.

[197] The word "experimentum" is close to meaning "experiment" here.

[198] "parietaria," a herb that grows on walls.

[199] The rest of this paragraph first appears in 1554.

Andreas Lacuna, a physician from Segovia,[200] tells of a medicament of Philip of Lusitania, which comprises alum, verdigris, orpiment,[201] and chalcitis,[202] in equal parts. When this is perfused with very acid vinegar for eight days, and ground up and dried in the sun, then the longer it is ground, perfused, and dried, and the more the sun heats it up, the faster it removes the flesh that has sprung up in the bladder neck and the genitalia, and the less the pain as it does this; in fact this is what the medicament is prepared to do. It is evident, then, that thick things are broken up by the sun and by acid vinegar, but it is grinding that reduces them to powder. And as it causes less pain, that occurs because burnt-up parts get detached.[203] The medicament, then, evidently gets more rarefied in quantity, but thicker and more equal in substance. This changes the body less by heating or drying. So what is very rarefied both in quantity and in substance corrodes more quickly; but when the substance is moderated, they occasion less pain. So what is thick in quantity and rarefied in substance causes pain, and &134 later is corrosive; what is thick in substance and thin in quantity acts later and without pain, like lime and gentle soap, on which I have spoken elsewhere.[204] What is subtle acts both ways, quickly and with great pain. What is thick in substance and rarefied in quantity corrodes fast and with little pain, and this is best. But an account will be given elsewhere of the application to human therapy.

But to get back to my subject: a doubt appears. If these waters are created by great heat, such as burning heat or that of separation, how is it that they are cold to the touch? Or if they are already chilled, how do they melt metals? Or if some heat has persisted, how is it not totally extinguished, even without movement? Or if it is assisted by some movement, why does it not ignite matter so inflammable? Experience answers none of these questions. But the same basis exists in natural mixtures too; sulphur is very easily ignited, and yet in itself it is cold. Pepper burns the tongue, and if it is eaten, inflames the body vigorously, yet

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[200] Count Andreas Laguna (1499–1560) of Spain translated Aristotle's *Peri Kosmou* into Latin and published it in Alcala in 1538. He wrote "Vita Galeni" (Venice, 1548) and "Libri octo ultimi ex Commentariis Geoponicis, seu de re rustica olim Constantino Cæsari adscriptis" (Cologne, 1543). Nenci (177 n. 101) has traced the reference to Laguna's *Methodus Cognoscendi, extirpandique excrescentes in vesicae collo caruncùlas* (1551), *Epistola nuncupatoria*, 3a.

[201] See n. 488 below.

[202] "rock-alum," from Durling. It is discussed in Galen (*De Simplicium Medicamentorum Temperamentis et Facultatibus*, 9. 35, K. 12. 241–42) and he says that then it came from copper mines in Cyprus. After a detailed discussion of Paulus Aegineta, Book 7, sect. 3, Adams (3: 399–402) concludes that it is copper sulphate and closely related to chalcanthum. See also n. in Book V at 380 (1560).

[203] "resolvuntur."

[204] In Book VII at 504 (1560): "The medicament [a painless scarring agent] is made from soft soap and quicklime finely mixed, so that it passes over into the form of a soft ointment."

it is cold to the touch, and when fire is brought to it, takes fire reluctantly. Philosophers ought to have looked into these questions which are established by the senses and encountered every day, and which when solved produce considerable utility, and should not have set aside points that we have awaiting our hands (the usual phrase), to study novel questions with novel names, in which you would be equally puzzled to make out &135 our query and to see how to resolve it. Then, even if the question is resolved aright a thousand times (which however hardly ever occurs), it could contribute nothing of use to the human race. An obvious sign of this is those eminent men who never discovered anything of use for life, over so many centuries, because they would labour under false principles, and just trifling noisily would be enough for them. So in order to avoid reproving them but turning out like them, I will now set about resolving this very necessary question.[205]

The first point to be made is that mixtures are believed to be made up from the elements, because in mixtures the qualities of the elements are evident, and hence too, as many elements are reckoned to be present in them as there are combinations of qualities, the reasoning not being conclusive. Another more straightforward indication is that in some cases (such as metals and stones) earth is clearly in evidence, but in others (such as herbs) water. What our eyes see is also to be introduced, that earth and water are the sole matters of mixtures, as the Philosopher[206] too said, under apparent inspiration, that it is heat itself which concocts these things during mixing.[207] So if there is much earth and heat, a fiery thing is created, as in the waters previously mentioned. If moderate heat has been present with much earth, it is called earthy. An example of the first is pepper, of the second, stones. If water[386] is in excess, very little earth may be there, but if there is great &136 heat, there may be something airy, which is all fatty and readily ignites. All the oils, fats, sulphur, and bitumen are like this. If there is little heat, things are watery, like most vegetables. Why then does pepper not ignite readily? Because along with the rarefied part there is a good deal of the earthy.

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205 The following two sentences first appear in 1554.

206 Aristotle.

207 Nenci (supported by a marginal note in the text: "2. de part. Animal. Cap. 1. in initio") traces as source here Aristotle, *De part. Animal.* II. 1. 646a12–20.—but especially, he wrote, *Meteor.* IV. 11. 389a29–b6, which runs (I have translated the *Latin* translation here, not the original Greek): "It must be understood that cold is in a sense the material factor (the Greek is simply "the matter"). For as dry and moist are matter (being passive), and find their principal embodiments in earth and water which have cold as a defining characteristic, it is clear that all bodies that are made of either element alone tend to be cold unless they have an external source of heat like boiling water or water strained through ash, which contains the heat from the ash; for everything that has been burned contains heat to a greater or lesser degree. The presence of heat is why worms are generated in rotten material, the presence, that is, of heat which has destroyed the material's own natural heat."

We have made clear that the earthy, which contains a lot of matter and prevents movement, resists the generation of fire.

But you will say, "Pepper is light." I reply, "This is because it is empty, but the actual substance is heavy, and if it is very well compressed, it is not light. And as sulphur is moist, it does not burn the tongue; however, it takes fire, because it is powerfully hot."

With these statements granted as principles, we proceed to the solution of the problem. In actual mixtures, only three items are evident: earth and water, and heat, which mingles them. For it is obvious that earth and water get mingled of themselves, but air avoids mixture, and you never can mix the latter with the other two, even if it were something more rarefied than that. But about fire there can be no doubt, since it neither is an element nor generates anything. Therefore if the mixed items were to comprise these, they would mix violently. But obviously fire does not generate, because it summons things out—what generates summons everything inward. Fire also dries, and things that are generated need moistness, because (as it were) it is what makes the parts of glues stick together. Once more, the fire separates and divides; but &137 generation requires crasis, not just mixture.[208] Fire also draws out qualities to a maximum. But what contributes to generation and what is mingled mutually break up qualities.[209] In conclusion: generating is the special function of celestial heat,[210] but not of fiery heat; indeed, fire is not life even in potentiality.[211] And fire mingles bodies, yet it divides and separates their substances. Hence by fire bread is cooked[212] but flesh is destroyed. However, we cook flesh with fire, since custom precludes our eating it raw. But if it were usual to eat flesh and eggs raw, it would do a good deal to prolong life. In fact, because it is not permissible to eat these things that can be eaten raw—milk, honey, oil, butter, sugar, and most vegetables of more rarefied substance—will do more good both to life and to health, if eaten. For

[208] In Book V, at 349–50 (1560), Cardano enlarges on his distinction between crasis and mixture, but not in complete concordance with what he says here in Book II: "Mixture is properly mentioned here; it occurs in three ways. One is mixture of unlike things and they change their form—this is called generation, which we will discuss here. Another is mixture of unlike things, and they do not all change their form—if it is of liquids, it is called crasis, as when water and wine are being mixed, but if of dry things, it is called mixture, as when millet and wheat and oats are combined together. And if they are alike things, it will be called a heap—and this is a fourth kind of mixture, as occurs when cereal is gathered together into a pile." He also remarks, in Book V at 356 (1560), that "nothing is generated except by a soul, because, as I said, it alone does mixing."

[209] "quae ad generationem conveniunt, quaeque miscentur, qualitates mutuo frangunt."—an instance of Cardano's lack of lucid Latin; I don't know which way this sentence should run, and which word is nominative—"what contributes etc." or "qualities."

[210] On celestial heat, see also Book V at 357 (1560).

[211] This clause too is ambiguous—are all these nouns nominative or what?

[212] "conficitur."

even if (as I said) fire does mingle bodies, and makes cinnabar[213] from sulphur and mercury, it still separates the substances of foods, and makes things worse by segregating thin from thick. And so, if distaste were no obstacle, eggs, oysters, and oblong shellfish would be better eaten raw than cooked. And overall, if their powers were strong, and distaste did not bother people, there would hardly be any need or use for fire in preparing meals. But people preferred to live in this way elegantly and not enough, rather than living for long but like beasts or peasants. &138 This is why I think that eating raw food contributed a lot to longevity in those who lived in the desert; for when raw things are being cooked, they are better than cooked ones which are spoilt by fire.[214] But it is best to be accustomed to this from childhood.

So heat is fourfold: one part is the main agent, that is, the sun's rays; a second is heat itself in actuality, but linked to dryness; a third is linked to wetness; but the fourth is the trace[215] of heat, not real heat. The first one we normally call celestial, and it is the origin and wellspring of the rest; being what it is, it heats,[216] but does not yet generate, because it is not linked to matter. Aristotelians would not call it heat; they are the people who pursue their case with daring in directions where they cannot be confuted. Indeed, no star is hot, because heaven is without any quality.

The second is fiery and is so called; it generates nothing, because being linked to dryness, it is more an instrument of destruction and separation than of mixture or crasis,[217] without which no generation can occur. Not fire alone, but every heat of its kind destroys, and is inimical to generation. This is why eggs taken out of cinders do not produce chicks.

The name of the third is natural heat, which itself requires movement, because all heat that thrives requires movement, and browses on the &139 substrate matter.[218] This heat is double: one kind has an obvious movement and resolution,[219] such as is present especially in complete animals, and more in those that have blood; or else it[220] has an obscure movement such as is present in plants, and much

[213] Nowadays the red compound mercuric sulphide goes by this name, and the evidence here is clear that Cardano refers to the same thing, although in the past there had been confusion with red lead (triplumbic tetroxide) and in classical times with the red pigment "dragon's blood" which was extracted from a tree (*OLD*). On the chemistry of cinnabar, its preparation and sources in antiquity, see Caley and Richards, *Theophrastus on Stones*, 193–202.

[214] "non ignis vitio carent."

[215] "vestigium."

[216] Scaliger (*Exercitatio* 23 [105]) takes issue here, asserting that there can be no heating in the absence of matter.

[217] On crasis, see n. 208 above.

[218] "subjecta materia."

[219] "resolutio."

[220] The other kind.

more in their seeds, and in metallic items. Yes, in these heat has an obscure movement, and yet disperses moisture.[221] The evidence is that over a year or two, seeds that are stored get dry, even if they are anointed, and they age like human beings, developing wrinkles, getting lighter and infertile. And heat is called a faculty, since its power, as in the case of pepper, is channelled off from the whole plant into the seed—and into a metal from a whole mountain, or from much of it, over-concocting what needs concoction, especially the earthy part. It is then rendered fiery, if much heat has been present; or if not much, a stone is formed. If much heat operates on watery substance, it gets fatty; if little, it gets watery.

Maybe you will ask whether heat actually persists. It does, but being natural, it is established[222] in moist substance, as pepper's heat is. Hence it cannot burn anything up, the more so since when a seed is pulled from a tree it finishes up very tiny. So pepper cannot be hot because of its natural heat, since that is extremely slender, nor because of its burnt-up substance, since that holds on to the trail of heat, not the actual heat. Similarly, alcohol[223] retains the&140 trail of heat, not the heat, and so does chilled ash. But lime holds on to heat for a while, and heat in dry lime;[224] this makes it hot to the touch, especially internally; the outside is in fact chilled by the air. And so if a little water is sprinkled on it, it usually ignites.

But you will say: fiery heat appears to be in moistness, as when a candle burns. But it is not; in fact it is supported from moistness, but it is not in the moistness. Similarly, though a human being may feed on apples, his substance is not apple substance, but fleshy substance; likewise, fire is fed by rarefied things whether wet or dry, but is established[225] only in something dry, and that something is very rarefied. This is the reason why the method of cooking fish in paper, just as in a frying pan, has been invented. Pick a single thickness[226] of paper (what we call papyrus), and lifting up the edges[227] on every side, pour on oil as you do into a lamp, and before it overflows, place on pure [387]charcoal without a flame. The oil shrinks from the fire and does not penetrate, nor does the paper take fire, because it cannot get dried owing to the oil's reluctance. Fire in fact does not start without extreme dryness, nor can flame or movement rarefy so that

[221] On the development of thought on heat in natural life, see Mendelsohn, *Heat and Life*, especially chap. 2: "Innate Heat."

[222] "fundatus."

[223] "aqua ardens"; see n. 127 above.

[224] Nenci. 181 n. 105, cites Aristotle's *Meteorologica* here, but the result is confusing because Aristotle's κονία does not mean "lime" but "dusty stuff or ash," yet gets translated into Latin as "calx."

[225] "fundatus."

[226] "simplex."

[227] "spondis"; "sponda" in classical Latin (*OLD*) only means a bed or bier or the frame of a bed, but in modern Italian it can mean a bed's edge.

fire can ignite;[228] however, it[229] gets warm gradually with change in the charcoal, and thus it heats up so much that the fish on it are cooked—a remarkable thing. But why does a thread round an egg not burn, not only in charcoal, but not even in a flame? Because there is no fire unless heat is brought to a maximum, and it is always prevented by the egg &141 from being brought to a maximum, because an egg cannot be burnt up. But what is not burnt up always cools what is extremely hot, in some way. On the same basis, cloth placed on polished crystal does not take fire from charcoal on top of it, even if you have blown on it with bellows.[230]

But if heat in moistness generates, why is there not generation in boiling water? Because that heat either is not in the substance of the water, or is also in something else which is dry. The evidence is that boiling water[231] burns like fire. But that it[232] is not in the substance of the water is evident because when the fire is removed, the water cools down of itself. But if heat is in wetness, it does generate; for instance, when flesh is out in the sun, little worms are generated, and worms in dung worms, and in Egypt, eggs covered up in dung give rise to chickens.[233] It is also related that long ago Livia Augusta[234] had cherished an egg in her bosom, taking turns with her servant girls, and produced a cock with a comb. But rotten heat comes from the kind of fiery heat, because it is dry; yet it is similar to natural heat, because it is associated with generation. It differs from fiery heat, because it does not possess obvious movement—but fiery heat does, and so there is a path from the one to the other. In fact, moderate fiery heat brings about decay, increased rotten heat scorches, burns, and makes a blaze. This is why such feverishness accompanies putrid fevers. The reasons are thus obvious why fiery heat cannot be converted into natural heat—fiery heat is dry, and cannot get more moist and like natural heat. Fiery heat also summons forth and &142 separates; natural heat draws inward and mingles. Indeed, all wet heat mingles. But natural heat can pass over into rotten and fiery heat, because what is wet is dried by heat. Hence, then, wet fire usually blackens things, because it summons

[228] Sentence obscure; "ignis vero non sine extrema siccitate nec flamma nec motus attenuare possunt ut ignis accendatur." The Latin contains no word corresponding to "start" or "exist" here, but I have inserted one in translation.

[229] The paper, presumably.

[230] This sentence first appears in 1560.

[231] "aqua fervens."

[232] The heat, presumably.

[233] Aristotle, *Historia animalium*, VI. 2, 559a30-b2; and he continues with the tale of a drunken Syracusan who incubated eggs successfully in the ground under his rush mat.

[234] Pliny (*Nat. Hist.* 10. 76, trans. Bostock) reported that it was not Livia but Julia Augusta, when pregnant in her youth by Nero, who used the expedient mentioned here to foretell the child's sex—and succeeded. Suetonius however (*De vita Caesarum, Tiberius*, XIV) tells the same tale of Livia, pregnant by Tiberius, that the cock with a comb was hatched, and a son was delivered—although of course the chance is about evens.

forth what is wet to the outside and drives air out; dry fire whitens, because it abstracts the wetness there was.

If fire operates on water and generates air, your next question will be, why then does it not generate fatty moistness? My reply is that fatness is the outcome of mixture, but fire separates. It separates on account of its own usefulness, because it expels what is watery and cannot be burnt, as in the case of green timber, which exudes water when kindled. But fat browses on what is moist, on which previously during life the natural heat was established. Therefore what is on fire must be highly rarefied and very dry, like chaff, alcohol,[235] and gunpowder.[236] But in this something earthy is contributed by the saltpetre,[237] and so it makes a bang. That is why people have tried to make a powder with the saltpetre taken out, one that would expel the bullet without a bang. This can occur if it is done slowly and without much force. And Brasavola[238] reports that the Duke of Ferrara discovered this,[239] but its range lacked impulse and was only about twelve paces. But (as I said) with great force it is utterly impossible to avoid the bang. For when the saltpetre is taken out, it will still be possible to develop gunpowder so that it expels a bullet, &143 and without a bang. But on the whole, what you have taken out of the bang is taken out of the impulse too. Consequently the substrate matter usually affects the fire and its powers, so much so that a fire made from coal or the solider woods (such as oak), or attached to stones or in metals, is seriously offensive to the eye, though almost harmless if made from willow and stubble.[240] In fact, the more solid the matter, the more intense[241] the fire. Indeed, all heat resembles its fuel.[242] Hence the solider fuels create a sturdier heat. Consequently a greater and livelier radiance, which dulls the spirits in the eye, also dries up and consumes the celebrated very rarefied moistness in which the power of sight is located. On the same basis, but more remarkably, metals liquefied by fire from softwood are made more tenacious, and softer. But the change of matter makes so much difference that the product is hard and brittle when derived from stronger woods. And it picks up the difference from a special nature

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235 "aqua ardens."

236 "pyrius pulvis."

237 "halinitrum"; see n. 48 above.

238 Nenci (183 n. 108) has identified the reference to Brasavola's *Examen omnium simplicium medicamentorum* (1545 ed., 588–89) which mentions that this Duke discovered this powder which propelled a projectile without a bang ("sine bombo"). For Brasavola's career see *Dizionario Biografico degli Italiani* 14 (1972): 51–52. Cardano wrote that he did not know him personally (Eckman, *Cardan*, 73).

239 This variant of gunpowder.

240 The following four sentences first appear in 1554.

241 "densior."

242 "alimentum."

and from the technique. It is weak[243] when placed underneath; for instance, when we cook meat it is put underneath, so as to act more strongly, since as we said, fire of its nature tends upward. Next to this is what they call reflex:[244] it occurs when the fire is applied above and below, or from a side, the opposite side reflecting[245] the fire's force. By this, soft metals are dislodged from the stones to which they are bound, and silver is separated from brass.

A third variety is that of ambient fire, when the thing we are seeking to burn or melt is surrounded on all sides &144 by fire without bellows. The most severe[246] method, the most violent, is when we seek to melt the most resistant matters present in the hardest rock. It is performed thus: vessels are made from black silica[247] with scattered white patches, four (or at least three) cubits in length, three-quarters of that in width, three fingers in thickness, bent at the bottom, and shaped almost like an elbow, without a base.[248] There is an opening in the middle of its length, and a channel in it precisely located, through which the draught[249] from bellows can be conveyed inward. At the bottom is an opening through which the molten matter can pass down. The lowest part of the vessel is blocked (the hole I mentioned remaining) with potter's clay[250] and ground coal, crushed together and brought to the consistency of cement and more tenacious. This arrangement is called metallic "Manicae,"[251] because of the resemblance.

The matter it is proposed to melt is inserted, along with this fire enclosed in layers of coals, exceedingly powerful, and everything that fails to melt must get burned up. The draught blown in from the bellows through the channel is extraordinarily useful. As is obvious, at the start it makes the fire blaze up and supports the flame, and causes the fire itself to penetrate more powerfully. Subsequently, since the draught is cold, it gathers the heat taken up by the metal and drives it inward, and thus liquefies the matter in which it is present. Thirdly, it prevents anything that has been melted from being burnt up, and moderates the heat.

&145 With these aspects examined, what remains is for us to disperse some uncertainties. The first is: if the heat present in the moistness concocts and generates, and also generates air (a hot and moist matter), [388]what is to prevent us putting air too in the mingled things? For there is cold and dry matter there, not pure earth, and cold and wet matter, but not water; in the same way, the hot and moist matter there present can be called air, and the hot and dry matter, fire.

[243] Reading "imbecillis" with 1554 for the "imbellicis" of 1560.

[244] "reflexum."

[245] "reddente."

[246] "extremus."

[247] "silex."

[248] "fundus."

[249] "spiritus."

[250] "argilla."

[251] Protective sleeves worn by gladiators.

In this way this issue will revert once more to the view of the Aristotelians. But there is a considerable difference. First, because there is no air here; air is actually made from fiery non-natural heat, and even if it were made, it is ejected. It is common knowledge that people who have a strong natural heat are devoid of flatus; but those with profuse bile and a hot nature, yet a modest amount of natural heat, have profuse flatus. Next: it is one thing to say that from the start of generation the four elements are mingled, but another thing to say that in mixed things after they have been mingled, parts can be found equivalent to these elements. A further point is that the part which appears similar to fire resembles this item of ours which it is agreed is no element. In conclusion, a more important point: when earthy and watery parts are separated, they reproduce[252] earth and water not in quality alone, but also in substances; but fiery and airy parts reproduce fire and air in quality alone, not in substances. And so, as was said previously, earth, &146 water, and heat generate everything in moistness, but from these, four substances appear to come into being, in accord with the resemblance of qualities.[253] Although in fact, as I said, air is the most cold by nature, however in mingled things there are four parts, differing in substance and powers. For earth, which when heat is ousted does not exist, remaining cold and dry, still retains the nature, power, and substance and name previously conferred upon it, even if it is hardly earth at all. But the portion of it which is overcome by heat, while remaining dry turns out hotter, and is called fire, either because it may be like our own heat, though inferior in powers, or because the ancients held a view like that about fire. On the same basis, water, which heat could not oust, is called water—yet it is not water; the part that heat overcame is referred to as air, because it is a hot and moist substance. In fact, the ancients thought that air was like that, despite the fact that, as I said, air is very cold—like all the other elements. And this question about the parts of mixed things is now clarified.

Another harder question comes next: if there is rotten heat in a dry thing, how does it generate? We supposed, indeed, that it is of fiery nature, yet manifestly it generates animals. And if it does this in a moist thing, how does it destroy?[254] But the reason it generates is that it is no different from a natural &147 substance. For since it is situated in a moist thing, it is regarded as natural for the things to which it is adapted[255]—but in things for which it is different and harmful, it is described as unnatural and rotten. For when flesh gets destroyed, the heat inside it is rotten for flesh, but for generating a worm it is regarded as natural. This is the reason why all rotten heat generates something, and also destroys something. Yes, as all the elements are very cold (as I said), with

[252] "referunt."

[253] The remainder of this paragraph first appears in 1554.

[254] The following material to [B] on 155 (1560) first appears in 1554, and it replaced material of which the text appears as Appendix 3 in Nenci, 315–16.

[255] "convenit."

the advent of heat they must be shaken and mingled, and generate something in keeping with the nature of the heat and matter—moisture[256] first, then fungi, then some sorts of herbage, then worms and snakes. Here the actual substance of the soul is evident, because it consists in some celestial heat. And therefore there is no rottenness that cannot be generation. And it is always the same heat that while generating the one, corrupts the other. When an apple nourishes a human being, that well-known human digestive heat is putrid to the apple, but natural to the human being. Yet the heat in seed is taken as more natural, it being a transitional stage to something more noble. But it is called rotten, when animals are generated which are inferior to those from which they are generated. Thus just as all the activity in the seed is for generation, unless it is obstructed, so too in the case of &148 putrefaction; by putrefaction it comes about that the work of nature is frustrated. Therefore all heat like this is termed "natural" and is preservative; but the different heat is called "rotten" and destroys. Yes, in wind-eggs the hen's heat is destructive, and generates something different, not a chicken, because that heat is not natural to it. But in eggs which are rendered fertile by the cock's seed, it is natural, and generates chickens.[257] Hence both natural heat and rotting heat are one and the same. If then all heat is described as rotten that destroys what is already in existence, even the heat in seed can properly be described as rotten; in the way that it destroys a plant's seed to generate a plant, and a donkey's seed to generate a donkey, and a human being's seed to generate a human being. Hence all generating heat will be rotten. But it is described as natural, since it generates something similar to what it is detached from, and more noble than the matter itself. But everything rotten generates something, and on that account is natural. Hence natural heat and rotten heat differ only on comparison—in fact they are the same. Indeed, all celestial heat generates and corrupts, and is either soul, or soul's instrument, or soul's cause—it is not an instrument, however, because soul came first, nor is it soul's cause, as in fact it is permanent; but it *is* soul. Hence Anaxagoras[258] put it well, that all things are mingled, and endowed

[256] The "hudum" of 1554 and 1560 presumably represents an unusual contraction "hudūm" which evidently = "humidum."

[257] In *De generatione animalium* (II. 5, 741a6–31; Loeb 203–5) Aristotle discusses how some birds can lay wind-eggs, proving that up to a point the female is able to generate on its own, but he is puzzled about whether these eggs are alive and what sort of potential soul they possess. Later (III. 1, 750b12–16; Loeb 273) he concludes that "as the region by the diaphragm is hot, these fetations reach perfection in respect of size, though for the purpose of generation they are imperfect, both in birds and in fishes, without the semen of the male."

[258] Anaxagoras (c. 500–428 B.C.) was the first philosopher to live in Athens, and the remaining fragments of his philosophy indicate that he considered that in everything there is a portion of everything *except* mind (νοῦς, rather than soul), which he viewed as an initiator of cosmic motion and the animating principle of animals and plants. (*OCD*)

with soul. For everything mingled is generated and destroyed; what does the generating and &149 destroying is natural heat; and natural heat is soul, or does not exist without soul. Therefore all hot things are mingled, and every hot thing is alive, or rapidly on the way into life. Indeed, this famous celestial heat never ceases till it has finished generating something, and what generates, generates in proportion to its potentiality and size. Hence, since this celestial heat is great in Egypt, it even generates complete animals, like hares and young roe-deer, without any seed. The heats of seeds differ from those of decay, because they possess more prepared matter. So there is less stench in the dissemination of seed than in decay, because it is composed of a less useless part.[259] But during the generation of animals from seed, there is much decay, evinced by the foul and corrupt menses which flow at childbirth.

But heat which does not generate lacks moistness of its own, but is either in excessive motion, or becomes exhausted, because it is not fatty moistness. Indeed, the principles[260] of generation are celestial heat and the moistness of the elements; this is why nothing is generated in ice (there is no heat there) nor in sand (there is no moistness there). In fact one of these qualities is the active one and the other the passive one, for no other quality is found, as I said, but the absence of moistness is dryness, [389]as the absence of heat is cold.

But you will say: "If soul is only celestial heat, it will not be a substance, but an accident." And if soul is only illumination, soul will still not be a substance, for illumination is open to destruction, because light is, and when the light is withdrawn, the illumination &150 is destroyed; hence it will neither generate nor preserve what has been generated. And if this heat is a body, it will be a body within a body, which was previously shown to be impossible.[261] And if it is without body and without substance, it will be an incorporeal substance in a body.

[259] Syntax obscure; "minus inutilis partis continetur" would be "minus inutili parte continetur" in classical Latin.

[260] "principia."

[261] "Sed dices: si anima solum est calor coelestis, non erit substantia, sed accidens. Et si solum lumen, corruptibilis est enim lumen, quia lux, et sublata luce, lumen et corrumpitur: quare nec generabit, nec genita servabit. Et si calor ille corpus est, erit in corpore corpus, quod esse non posse superius demonstratum est." This passage is fraught with uncertainty and ambiguity in the Latin. Where does what "you will say" end? On the question of *lux* vs. *lumen*, Lindberg (*Theories of Vision*, 113, 124, 134) draws on Henry of Langenstein (ca. 1380) for the view that *lux* is a "natural agent, luminous quality of a bright body," while *lumen* is the "instrumental quality or species issuing from it." And similarly from Buridan (ca. 1295–1358) at Paris: "*Lux* has a fixed existence in the lucid body. *Lumen* is transparent, and does not terminate and bound its subject, and does not have fixed existence in it. Alternatively put: *lumen* is the species of *lux*, its image or representation in the media. It is *not* perceived, but is the agent by which *lux* is perceived." Putting it another way, *lux* is the power which a shining body has; *lumen* is the effect of that power. Presumably if the sun released *lux*, it would run out of it . . ."

Those who hold that this heat is the soul appear to labour under difficulties of this sort. But the heat in question is not a body, nor some impression, and for that reason is not an accident either, nor a body penetrable by another body; but it is described as corporeal, because it cannot exist without a body. So what we had proposed from the outset is obvious, that everywhere there are five principles: matter, form, motion, place, and soul. But soul is a form, but not the one that is linked with matter at the beginning. A soul therefore is a form,[262] but not of the same kind[263]—for if it were, there would be four principles. So let there be a different form,[264] and the rest is completed. Therefore every soul is permanent in the same way, and not, as Plato says, only the souls of the perfect animals, for it would be as if we were to say that the souls of blind or dumb human beings are different from those of perfect human beings. This complies with what was said in the book *De Animi immortalitate*,[265] and it was proved in the books *De arcanis aeternitatis*.[266]

But for the moment it may suffice to have stated this much, since these heats are of the same kind as &151 souls, but differ like contraries. Nor is it only what is generated without seed that is contrary to what is generated with seed, but also what is generated with seed is in turn contrary, as vipers, scorpions, and spiders are to oxen and human beings. For if they have wounded a human being with their teeth and sting and claw, they make his body decay and corrupt, even sometimes killing him. So when earth and water have been too little concocted, there emerges a generation of inferior animals, such as worms. But if there has been vigorous mingling, and heat that is powerful or plentiful, yet temperate, plants or more perfect animals will be generated, but especially with the help of

In his *De arcanis aeternitatis*, cap. 5 (*Opera omnia* 10. 7) Cardano does remark that the Sun's light and illumination are both "eiusdem" (of the same origin), but light is eternal, illumination is not; it is in fact not actuality but the similitude of actuality.

[262] Or perhaps, "a form therefore is a soul."

[263] Of the same kind as the standard form.

[264] That is, a different form, the soul—as well as the form essential in hylomorphic theory.

[265] But this time the word is "anim*us*"; the work *De immortalitate animorum* was published in 1545, and is described by Maclean, *De libris propriis*, M55, pp 73–4.

[266] In Cardano's *De Arcanis aeternitatis* (see n. in Book I to 5 [1560]), he wrote that animals have souls that work upon their bodies, and are aware of what their senses perceive, and generate and love beings very like themselves; and plants too have a soul that controls them and draws in what they require, though they wholly lack sensation, and they generate seeds and offspring: "Animalium quoque animae corpora sua agunt et cognoscunt quae sensibus percipiunt et generant sui simillima et illa diligunt. Plantae etiam animam habent, quibus reguntur et quod necessarium est trahunt quamuis omnino sensibus orbatae, et semina prolémque generant." But I have not succeeded in identifying any passage in this discursive work amounting to what is outlined in *De Subtilitate* here.

unrelated[267] seed, or seed from the corpses and bodies of others. These are more broken up,[268] and deviate less from the power of the generating heat in respect of their impressed qualities or their particular coldness—for that reason the matter conforms better to it,[269] and mice are created, snakes, hares, beavers, river bass[270] which no sensible person would deliberately add to new fishponds, and yet they soon settle in together.[271] Thus though heat is one thing, there are a number of types[272] of it. In this way some of them suit us, but others do us harm. The reason this happens is that though their[273] heat is located in moistness, it does not suit human moistness; it is overwhelmed by something, dispersed by something. Thus contrariwise, a modest natural heat gathers &152 moistness together, another heat burns it up. Though then all fiery heat burns things up, yet not every heat that burns up some moistness is fiery—only the kind that is fiery for it.[274]

Dry things, then, do not decay; what decays fastest and most is what is endowed with watery moistness. Midway are fatty things, such as bacon, oil, nuts, almonds, sausages. Things that decay in this way smell bad, but they do get eaten, especially by people of less discriminating[275] palate. It is the same with salted fish—nothing more so. But there is room for doubt, because things devoid of heat should rot more in watery environments, yet heat rots everything, as we said. But the reason why things of this sort (such as flesh, and stagnant water) do not rot fast nor completely, is that as decay develops from a heat that is contrary to nature,[276] things like fatty ones that hold on to much innate heat rot more slowly; in fact they grow bitter as they turn rancid. For when decaying heat rots something fatty, it passes over into bitterness, either from a sweet or from a fatty flavour. Insipid things consequently do not decay like this, but salty ones, fatty ones, bitter ones, tangy[277] ones; this is, as we said, the effect[278] of hot things.

The cold flavours are: sour, acid, bitter, astringent, and insipid. The rest are the hot ones, such as fatty, sweet, salty, pungent, tangy—the hottest of all. So this is why oil of an acorn (for &153 ointments), of a sort of acorn which is correctly called myrobalanum (this is not myrobalanus, and this name does not

[267] "alienus."

[268] "magis refracta."

[269] The heat, evidently.

[270] A fish.

[271] "coalescunt"—my translation may be stretching things, but *OLD* does give "become unified" and says that in Tac. *Hist.* 2. 7 the victors and the vanquished "coalescere."

[272] "species."

[273] I.e. that of the harmful kind.

[274] "sed illi tantum igneus."

[275] "delicatus."

[276] "putredo à calore contrario naturali fiat."

[277] "acuta."

[278] "passio."

suit it, because it is almost devoid of odour and flavour),[279] being, so to speak, temperate, does not shrivel up. So perfumes are admirably extracted from it by ointment makers. Hence a thing that turns rancid gets bitter and dries up (and this happens with the passage of time); but things dissolved in olive oil do not turn rancid, and sausages are preserved in that way, and go bad less in the open air, because they do not heat up.[280] The oil itself, being plentiful, is not corrupted, because the surrounding air is the reason for corruption, and oil is strongly resistant. Thus wine in bulk, water, oil and everything lasts longer through its quantity.

But as everything that cannot completely decay gets eaten away through the passage of time, everything gets like that in time—sausages, nuts, pistachios, pine nuts,[281] and anything containing an oil. For even salted fish possess an oil, both on the basis of salt and on the basis of flesh;[282] and as I said, even all fatty things. Yet as long as moist things are very much so, they do not start to decay, but if they are suitably fatty, they are preserved; or if they are less so, they develop mould, and some do decay. And while these three—mould, rancidity, and decay—develop from mild heat, when the heat is vigorous they are largely prevented. A general characteristic of every sort of decay is a stench—in mould a heavy one, in rancidity a rancid one, in complete decay a foul one. But in caries[283] the &154 smell is minimal, because it arises in something earthy. It is in fact readily shown that there are four kinds of decay, neither more nor fewer. Things that go rotten are either completely corrupted and are called putrid, or not completely, and in that case (or on account of coldness) are not completely corrupted, and it is called mould; or it happens on account of heat, and it is called rancidity; or it happens on account of dryness, and it is called caries. Decay cannot be hindered because of moistness, but provided the substrate for decay is moist, it either totally prevents decay, or totally decays because it is moist. Yes, moistness does not delay decay of itself, but because of either heat or cold. This is why it is easy to prevent decay in mould and in genuine decay, by

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[279] I have translated as "myrobalanu*m*"; since the case is accusative, the word might be this or myrobalanu*s*; for passages in Galen where this word appears, as μυροβάλανος, see Durling, *Dictionary*, 241; under myrobalanu*m*, *OLD* gives "The ben-nut; its fragrant oil," and under "ben," *Chambers' Dictionary* gives "any of several tropical trees of the Moringa genus, especially the horse-radish tree (*Moringa oleifera*), its seed (ben-nut), yielding ben-oil or oil of ben, used as a lubricant and in the preparation of perfumes and cosmetics." Nowadays, *Myrobalanus buceras* is a synonym of *Bucida buceras*, the black olive. In his remark about absence of odour and flavour, Cardano may be thinking of myrrh, the aromatic gum extracted from the bark of a specific tree, although the words myrobalanum and myrrh are not linked.

[280] Though they would in a confined space.

[281] "pineae."

[282] "tum ratione salis, tum ratione carnis."

[283] A rot of wood, or a shrivelling or drying up of bone or living tissue (*OLD*).

removing the [390]watery component. This is the case firstly[284] with fires, as in baking bread, and with fat, which when cooked does not decay; and secondly,[285] if little moistness is present, as in salted meat, it is preserved by coldness and dryness, as is air while in motion. For while it is in motion, it is cold and dry—cold through its nature, dry through the motion—motion does dry. So this is why still air leads to decay,[286] because it moistens, and does not chill as much as is required; so long as it is in motion, it preserves, drying through its motion, and powerfully chilling.[287] It follows that through exposure to the air many things get rotted which otherwise were staying intact; others are preserved &155 which would rot without the air's help. And so not only these things, but others to be mentioned later, are preservative[288] against decay. Moist things are protected against rancidity and caries, and so are things that get in the way of the air's movement—they get dried up by it. But since such things are excessively hot or dry, they would be corrupted without decay, even if preserved from decay by the help of fire. The causes and kinds and prevention of decay have now been sufficiently covered. [B]

It then remains for us to discuss how that actual Sacred liquor we mentioned previously[289] is no closer to the Elixir which my father created. Timber and herbage (mostly odorous) are extracted with alcohol,[290] and they half-decay covered in dung, so that (as the phrase goes) the more rarefied part is separated from the earthy one, and then we remove all that is best by distillation, leaving only the sediment. This product strengthens the teeth, and postpones grey hair, it helps concoction, memory, and the senses, but is far inferior to the Sacred liquor, even though that carries along many people into a prolonged old age.

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284 "vel."

285 "vel."

286 "corrumpit."

287 Aristotle's account of this subject (*Meteorologica*, IV. 1, 379a26–b6; Loeb 295–97) runs: "And there is less decay in cold than in warm weather: for in winter the amount of heat in the surrounding air and water is so small as to be ineffective, while in summer it is greater. Again, what is frozen does not decay, as its cold is greater than the air's heat, and therefore is not mastered by it: but what causes change in a thing does master it. Nor does anything boiling or hot decay, because the heat in the surrounding air is less than that in the object, and so does not master it nor cause any change. Similarly, what is in motion or flowing decays less easily than what is static. For the motive force of the heat in the air is less than that of the heat residing in the object, and so causes no change. For the same reason large quantities decay less than small ones: for the larger quantity has too much native heat and cold in it for the properties of its environment to master. Therefore sea water in small quantities decays rapidly, but in bulk it does not: and the same is true of other kinds of matter. Living things are generated in decaying matter because the natural heat which is expelled compounds them out of the material thrown off with it."

288 "servant."

289 It is not clear where; evidently not in the present work.

290 "aqua ardens."

But you will ask: "If rotten heat corrupts, why does fiery heat not do so, being of the same kind?" The reason is that fiery heat is external, but rotten heat is internal; that is why fiery heat attracts things towards it,and dries the interior by drying and attraction, and prevents decay. Though putrid heat does dry, yet being internal, and attracting things towards it (in fact all heat does so), it moistens &156 the interior and rots it. So putrid heat makes common cause[291] with fiery heat, because it is itself drying and it generates—and with natural heat, because it lies in the depths and causes corruption. This is why putrid heat is correctly described by some people as midway between fiery heat and natural heat. For it is similar in substance to fiery heat, and to mould in its natural relation to food; for always, fiery heat is located outside food. But you will ask: "Why is putrid heat the originator of poison, but fiery heat opposes all poisons?" For if wounds arising from poisonous animals are cauterised with white-hot iron, they become free of poison,[292] and medicaments of any sort, on being burnt and reduced to ash, stop being poison; but on being sublimed[293] (the current word for what in antiquity was called "concocted"), the more often this is repeated, the more dangerous they get, and the more rapidly lethal. In the case of decay and of sublimed things, the reason is the same: when the heat is increased and the moistness is not restricted, as in the case of things getting cooked or rotting, the poison's power is augmented. But when they are burned, since all the moist part passes away and at the same time the heat is restricted, as in ash, the poison's whole power has to depart. So it was not ludicrous for someone to be curing plague with sublimed mercury, for every poison is assessed[294] by its fiery power.[295] Ausonius put this aright:

[291] "convenit."

[292] This belief goes back at least to Aulus Cornelius Celsus, who wrote his *De Medicina* probably in the first years A.D. and (Book 5. 27) advised that the bite of a mad dog be cauterised to destroy the poison. The advice was reinforced by Jean de Vigo (Ioannes de Vigo) in his *Practica in arte chirurgica copiosa* (Lyons, 1516) and, when applied to gunshot wounds, was famously opposed by the French surgeon Ambroise Paré while in attendance on the injured of the army of Francis I campaigning in northern Italy (1536); he included in his "*Apologie and Treatise*" the "First Discourse wherein wounds made by gunshot are freed from being burnt or cauterized according to Vigoes Methode."

[293] This word denotes especially conversion from solid to vapour without any intervening liquid state, and applies to mercuric chloride, which vaporises below its melting point. Hail on the ground too can be seen to do this outdoors on a dry but breezy cold day, at a temperature below freezing point.

[294] "finitur."

[295] Metallic mercury is relatively safe to swallow, because it is very poorly absorbed; in the epoch of mercury clinical thermometers, the mercury (and glass) from one inadvertently broken in a child's mouth might get swallowed without disaster, and Rhazes (ca. A.D. 854–935) agreed: "I gave a draught of it to an ape, nor did I perceive any inconvenience arise from it, except, as I have mentioned, that it appeared to be pained in its

> An adulterous wife gave her jealous husband poison, &157 and though too little had been given to kill; she mixed a deadly weight of mercury, so that the doubled power would inflict a speedy decease.

Then he added, a little further on:

> Thus while the harmful draughts struggle against each other, the deadly harm gave way to preservation.[296]

For as I have said, sublimed mercury has the characteristic of fire. However, the man who used to try to cure plague like this used to slaughter more people than he cured with his medication. If then a harmless and fiery medicament is being prepared, it will be able to cure. Yet whatever its sort, it weakens the natural heat, as also do hot cloths applied externally. But contrariwise, a small boy or a fat puppy applied to the stomach is a great help to digestion, and increases the natural heat, though it is not the same heat — no, it differs from the puppy's heat even in kind.[297] So it is clear that when natural heat is not interfered with by another natural heat, it is reinforced by movement, as something fiery is reinforced by something else fiery.

With that cleared up, let us return to the account of the elements, which we explained are three: air, water, earth. And it was not essential that air be mingled in generation, since heat is hardly suited to being passive; the elements contribute by being[298] matter, a function for which earth and water were enough. But not to contribute heat, since a different heat was needed, celestial in &158 origin, and it was also enough for the task, since with two heats (as with two principles) things would have gone ahead less well, and cold elements would not have complied with an unrelated heat, and one of a contrary element. What is more, that would have been a battle, not a generating. Perhaps someone will be astonished that I should have felt differently in the *Libri contradicentium*.[299] But the intention there

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belly, for it often bit it with its mouth, and grasped it with its hands" (*Almansor* 8. 42, cited by Adams in his edition of Paulus Aegineta, 2: 238–39). On the other hand, after heating with vitriol and thus acquiring "fiery power," mercuric chloride is formed, the very poisonous "corrosive sublimate" of mercury.

296 These two quotations are from Ausonius of Bordeaux (ca. A.D. 310–394), *In Eunapiam adulteram* (1–4 and 7–8): Ausonius, *Epigrammata* 13. 10: R. P. H. Green, *The Works of Ausonius* (Oxford: Clarendon Press, 1991), 68, 383.

297 "species."

298 "ut."

299 Girolamo Cardano, *Contradicentium Medicorum Libri Duo* was one of the author's earliest books. It was composed in the 1520s, but its first publication was at Venice in 1545 (Maclean, *De libris propriis*, M13 [51]). In *Contradicentium Medicorum* lib. I tract. 1 contradict. 11 (*OO* 6: 307–9) Cardano does indeed review the role of heat, referring to Galenic and other earlier views, but is not emphatic about the Galenic role of natural

was to retrace the views of the ancients: here it is to teach the truth. So what was the reason for the creation of the element air? It was for it to be spread below the stars' rays,[300] and receive their powers; it receives them to such an extent that in abrupt changes it could kill not just animals but even plants, for instance in this year 1549, in a period of three days it dried up all the bitter oranges[301] of Liguria,[302] in a significant prodigy.[303] The explanation is that coming on top of heat, it assails the exposed bodies of both plants and animals, and quenches their internal heat. Not so long-lasting is the cold which creeps up little by little, though it may have extended further. But this could not have come about if (as people relate) the air had been extremely hot of itself. And this is why it became transparent and very cold, so that it was healthy and agreeable for animals, not (as they say in jest) very hot and damp.

But what reinforces this view and solves a tricky question is this, that while exhaling air with their mouths wide open, people get hot, while if they do it with pursed lips, they get cold. In fact it is obvious that the &159 reason is simply that what is cold of itself, [391]conveyed along with effort, is obliged to leave hot vapours behind it; and by itself too it enters the pores of the skin with the power of the effort. With these two features it is markedly cooling, and neither of them occurs if you exhale with your mouth wide open, and gently. But if you do it either quickly[304] with an open mouth, or with a pursed mouth and a hand held close, you will actually warm up a little, or barely cool. Breath[305] of any sort warms the closed hand too, even if propelled with vigour, because vapour is hot and cannot exhale. Hot vapour, because it emerges from the mouth, cannot be exhaled with the hand closed; but it is chilled by motion in an open environment, and reverts to its special nature. In fact, the air conveyed to us by south winds,

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or innate heat in the animal body: "Ex his verbis luce clarius est, Principem [i.e. Galen] velle aërem esse principalem causam exsiccandi corpora nostra: calorem autem naturalem quasi per consequentiam." And he inclines to regard heat in animals as the celestial, not the fiery, heat, and to answer the question of this *Contradictio*, "Humidum radicale an à calore naturali consumatur?" with a "No."

300 These would include the sun's rays.

301 "citrangula"; the word is identified with the bitter or Seville orange (French "bigarade"—used in Britain for marmalade) by G. Gallesio, *Traité du citrus* (Paris: Fantin, 1811), 123.

302 A long coastal region of northern Italy centred on the port of Genoa.

303 On the interpretation of prodigies in the thought of various thinkers over a long period from Aristotle onward, see Jean Céard, *La nature et les prodiges* (Geneva: Droz, 1977), also Lorraine Daston and Katharine Park, *Wonders and the Order of Nature* (New York: Zone Books, 1998).

304 "Quickly" is probably the key word here: breathing out *rapidly* encounters some measure of obstruction, which according to Cardano keepts the heat inside, yet lets the cold out.

305 "spiritus." The material to [C] on 161 (1560) first appears in 1554.

hot though it is, is so because of vapours; this is why it is always cooling on mountain ridges. The evidence is the hailstorms which descend in midsummer, and from the south, and no higher than the mountain peaks; hail is extremely cold. But it was necessary for the air to be in continual motion, so that it could be preserved and shed all its alien quality. And the evidence that air is always in motion is that in confined spaces a breeze is always blowing. Although in fact it is always in motion higher up, and constantly restless, here lower down it always blows gently; and when it has an exit from a crack, it thrusts violently with its whole &160 concerted force, because of the confined space, resembling the waters in great rivers, which may look almost stationary, but when passing through confined spaces or the so-called "cauldrons,"[306] they are forced to burst out with huge effort and noise, and a great crash. Movements, and other things which arrive with continuous substances, gather things together—also where a substantial mass is confined in some restricted situation. Hence we are instructed to construct very cool cloisters[307] by arranging numerous narrow recesses into them. And in Egypt, when the air seethes with excessive heat, a plan was devised for very lofty towers, in which narrow coils[308] running obliquely from the top point lead very chilly air downward, because it is colder through being extracted from a purer environment, and because of the distance traversed, it travels with a great rush, and hence emerges very cold and makes a rather powerful impact.[309] And external heat is fended off by a wall's thickness. Also, the obliquity of the location prevents the Sun's rays from entering, though light gets in. On these four

[306] "conchae": I surmise that here this word carries a meaning that "conca" possesses in modern Italian: "cauldron (oceanog.)."

[307] "cryptoporticus."

[308] "anfractus."

[309] Pory's English translation of Leo Africanus (Book 8, "Of the qualitie and temperature of the ayre in Egypt"; 3: 859–60) evidently reveals Cardano's source here: "In sommer time this countrey is most extremely hot, for a remedie of which heat they build in euerie towne certaine high towers, hauing one doore aloft, and another beneath, right ouer against the houses, through the tops whereof the winde passing downward, doeth somewhat coole and refresh the ayre; otherwise in regard to the intollerable heat of the sun it were impossible for any man to liue there." But the "coils" seem to be Cardano's own idea, and do not appear either in the Italian of Ramusio's version, cited by Nenci (199 n. 126). Johannes Leo was a twenty-five-year-old Arab, born probably in Spain and originally named al-Hassan ibn-Mohammed al-Wezaz al-Fasi. Captured in North Africa by Italian pirates in 1520, he became a protégé of Pope Leo X. Leo persuaded the young man to become a Christian, gave him his own name, and later persuaded him to write an account of his travels on the then almost unknown "black" continent. Hassan became Leo Africanus, and his book was translated into several European languages. For nearly two hundred years, Leo Africanus was read as the most authoritative source on Africa. For a recent biography, see Natalie Zemon Davis, *Trickster Travels: In Search of Leo Africanus* (London: Faber & Faber, 2007).

plans, it is possible to construct in any very hot region very congenial and healthy retreats—they are healthy, because they get blown through.

But you will say: "We see, in the case of fans placed on the summits of towers, made from very thin and light rotating metal layers, that only the winds move them, and otherwise they are at rest; so the air is not always in motion." &161 When we actually wish to know from where the winds are blowing, we check the direction to which the fan blade is facing and is at rest, and know that the wind is in the opposite direction. But if the fan blade is at rest in several positions, the winds are blowing from the same number of opposite directions as there are positions in which they have settled—for instance, if the fan faces to the north, the wind blows from the south; if to the east, it blows from the west; if now to the north, now to the east, both winds are blowing. And the same principle is to be followed both with other winds and with a number of winds. Hence we are taught to position that Triton of Vitruvius.[310] But when no winds are blowing, the air gently wafts to one direction, and the fan tends that way all the time; thus the air is not being stirred, yet it is always blowing. But when a calm is in force, with movement of air from the east, the fans actually incline to the west; and this is the natural motion of the air. So air is very cold, and in continuous motion. Nature has also made it very rarefied.[C] It is thus very rarefied too so as to absorb all impacts. Certainly in earth only imperceptible movements occur, it being solid; in water too they are sluggish; air alone is ideally suited to absorbing impacts, and this very rarefaction appears to be why.

There are four simple motions in addition to the three already mentioned. Celestial motion, which is the most natural; and another also natural, which is the product of some compliance in things,[311] &162 such as the compliance of the waters to the Moon, and of iron to lodestone; and voluntary motion, which is suitable for animals. The fourth after these is violent motion, which is in line for discussion now, since we shall speak about the others in their place. The simple motions are seven in all, and complex motions arise from them. And so, when the Philosopher[312] had accepted the statement that nothing moves without something moving it,[313] and that what is moved by a violent motion does not have the motion's origin within itself, because its motion is purely violent, the reason being that its origin is external, it follows that what is violently moved

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310 Vitruvius (*De Architectura*, I. 6. 4: Loeb 1: 5–7) describes a Tower of the Winds built at Athens by Andronicus of Cyrrha (a town in Syria), who flourished about 100 B.C. On top of it was placed a bronze effigy of a Triton which rotated with the wind to show wind direction.

311 "quadam obedientia rerum."

312 Aristotle.

313 "motor."

is being moved by something external to the moved thing.[314] This is impossible unless air is doing the moving, so what is moved violently is being moved by air. And doubt was settling[315] on this same air, over one statement which is true, that every moving body is being moved, and hence if air moves a projected stone, the air is being moved—and so we are stuck, as in the case of the stone.[316]

People say that as air is light, it is being moved by its own form, and therefore four views have arisen in relation to this point, none of them grasped by the commentators, and particularly Aristotle's view, of which they make so much. The first of the four is that a moved thing, like the stone A,[317] is moved by a force acquired from something that is projecting it (in the way that something heated up by a fire later heats up other things with its acquired heat, and itself stays hot for some time); in this fashion a &163 moved thing receives from the moving thing the force through which it is carried along, till it comes to rest.

This is a tenable[318] view, which was rejected on an argument of the ancients brought up by Aristotle.[319] But it can be demonstrated that movement by the air

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[314] Compare here (as cited by Nenci) Aristotle, *Physica* VIII. 10, 266b27–267a1 (Loeb 417) "If everything that is in motion is being moved by something, how comes it that certain things, missiles for instance, that are not self-moving nevertheless continue their motion without a break when no longer in contact with the agent that gave them motion?," and Aristotle, *De Caelo* III. 2, 301b17–23 (Loeb 279–81): "Nature is a cause of movement in the thing itself, forces a cause in something else, or in the thing itself regarded as something else [Simplicius illustrated the meaning of this last clause by the example of a doctor healing himself; it is only accidental that the force and what it acts upon are united in the same concrete object; what heals is the physician's art in his mind—what is healed is his body]. All movement is either natural or enforced, and force accelerates natural motion (e.g. that of a stone downward) and is the sole cause of unnatural motion." Philoponus for his part developed the impetus theory in the sixth century.

[315] "cadebat in."

[316] Presumably he means that an infinite chain is starting. Nenci cites Simplicius here (201–2 n. 130) but there isn't any stone there.

[317] This just might mean "the stone at A"—see the text box figure below.

[318] The Latin word is "sensibilis,"which *OLD* and *L&S* give only as "capable of being apprehended by the senses, or capable of sensation." Subsequent dictionaries (DuCange and Forcellini) do not endorse the modern meanings of "tenable" or "sensible" in the current sense. *OED* traces this use back only to approximately 1650. Professor Richardson kindly pointed out to me that "tenable" is part way to to-day's "sensible," the latter including a nuance of approval stronger than "tenable" does.

[319] "quae antiquorum est argumento ab Aristotele adducto reiecta"—a passage perhaps relevant (though not rejecting the view here) is Pseudo-Aristotle, *Mechanica*, 32–33, 858a13–23: "Why do objects thrown ever stop travelling? Is it when the force that discharged them is exhausted, or because of the resistance, or because of the weight, if any of these is stronger than the discharging force?. . .Why, again, does a body travel at all except by its own motion, when the discharging force does not follow and continue to push it? Surely it is clear that the initial impulse given causes it to push something else in

occurs, because a thunderbolt still demolishes trees without touching them. A second view was Plato's, that, for instance, O through motion is transferred by a moving thing right to B; when it is left there by the moving thing, the mobile air previously at the space (i.e. at A) fills the space between A and B, and so it touches the movable A with motion, and in this way it always fills up the space which the movable A abandons, with the impact with which A is already being moved; this is inevitable on account of the movement of rarefaction,[320] or so that a vacuum does not arise. So Plato can argue along this line: air follows after anything moved by whatever impulse,[321] by filling up the space by the same impulse, and it touches the A that has been moved, therefore the air itself will move A by the same impulse as at first, by making an unbroken movement. And he calls this style of movement antiperistasis—that is, through change by a succession of places.[322] [392]Aristotle says that motion does not occur in this style, because even if antiperistasis were going on, a movable thing could not be

O A
. B
. C
. D
. E
. F
O G
. H

the first instance, while this in turn pushes something else; it stops when the force which is pushing the travelling object has no longer power to push it along, and when the weight of the travelling object pulls it down more than the power of the pushing force can drive it forwards." The author sounds puzzled; when his hand keeps on pushing the object, the case is clearer, but when it throws the object, less so. Aristotle (*Physica*, IV. 8; 215a1–24) considers projectiles, and when they are no longer in contact with the body that propelled them, they still move; is this due to a "circulating thrust" (ἀντιπερίστασις) or to "the air being set by the original impact in more rapid motion than that of the natural movement of the missile towards the place proper to it"? The "circulating thrust" may be in Cardano's mind as the view "that was rejected." See R. Sorabji, ed., *The Philosophy of the Commentators*, vol. 2, *Physics* (London: Duckworth, 2004), chap. 22, "Dynamics," 327–56.

320 "raritatis motum."

321 "impetus."

322 Aristotle, discussing the motion of projectiles in *Physica* IV. 8, 215a14–19 and VIII. 10, 266b27–267a21, uses this word *antiperistasis* (in Greek), and it is rendered by Clagett (*Science of Mechanics in the Middle Ages*) as "mutual replacement." The explanation of "change by a succession of spaces" is due to Simplicius (*ad Phys.* VIII. 267a12) commenting on that passage. There is a detailed discussion of this and other senses of the word "antiperistasis" in Lee's Loeb translation of Aristotle's *Meteorologica* (82 n. b), and also in Heath, *Mathematics in Aristotle*, 157. It could be invoked to account for a wide range of phenomena; for instance, Partington (*History of Chemistry* 2: 77) points out that Aristotle believed that well water was colder in summer than in winter, because the air's warmth made it so through "antiperistasis," and that Bernard Palissy (1509/10—1589/90) followed him in this belief. Nenci's notes (200–5) provide extensive valuable citation from Aristotle, Simplicius, and Averroes. Nenci also (143 n. 44) points out that the heat released when water is added to quicklime (noted by Albertus Magnus) might be regarded as produced by the coldness of the water, through "antiperistasis," in the same way as a little water sprinkled on a declining fire may rally the fire. I note that Nicholas Oresme (b. ca. 1320, d. 1382) was also impressed by the phenomenon of quicklime heating up; see Bert

propelled by it. His reasoning runs like this:[323] things that make movement[324] by antiperistasis are also being moved, so while they are not being moved, they do not make movement. But when the air present in A was in B, at that time it is not being moved by anything, indeed it possessed the place that it was bound to occupy; &164 so it cannot move A from its location while A is in B. This is clear, since a body does not move another body unless when the mover itself is being moved. And this argument was not grasped by the commentators, and yet it shows clearly that Plato's view is false.

A third view is that of some of the ancients, that air going ahead of the movable thing (suppose at C, while the movable thing is at B) is moved towards D, and through replacement[325] to avoid a vacuum, B is transferred to C into the place of the moved air; and thus the same air is moved from D to E, and the movable thing follows through the same impulse.) It is as if an ox were to occupy the place or the role of the air going ahead, and a cart that of the weight or the movable thing, and the link by which the ox pulls the cart is rarefaction or the compulsion[326] of a vacuum. Thus however much the ox gets moved and however fast, the cart will get moved as far and as fast, and so however far and fast the air in front of the movable thing A gets moved, the movable thing A will follow, and thus the movement will become continuous.

And this was the view of some of the ancients, a view which some thought erroneously was the Philosopher's, but since it is abandoned by him (the same argument campaigning against it as was brought against the first view, that if air at C is moved to D, what is doing the moving?[327]—if something mobile, then they will move each other in turn, which is impossible, for a movable thing would propel air from C into D; and now it is proposed that &165 air translated from C to D would drag a movable thing from C into D, therefore cause and effect will be the same thing related to the same thing).[328] If you suggest that air transfers itself, he says: "Why then can a movable thing not do this?," and the first opinion returns. If you suggest that air can do this because it has a principle of motion,

Hansen, *Nicole Oresme and the Marvels of Nature* (Toronto: PIMS, 1985), 65. On the very similar *antispasis*, see n. 27 above.

323 "Ratio sua (*sic*!) sic se habet."

324 "movent."

325 "successio."

326 "necessitas."

327 Pseudo-Aristotle, *Mechanica*, 33, 858a17–23, mentioned previously, runs: "Why, again, does a body travel at all except by its own motion, when the discharging force does not follow and continue to push it? Surely it is clear that the initial impulse given causes it to push something else in the first instance, while this in turn pushes something else; it stops when the force which is pushing the travelling object has no longer power to push it along, and when the weight of the travelling object pulls it down more than the power of the pushing force can drive it forward."

328 Syntax tortuous and probably incomplete.

the consequence is that that motion will be perpetual, because this air will always stay the same, and will be moved by its form, always therefore with equal speed. But both of these are at variance with experience—because a stone projected in this way would travel from the hand through all the world, and with equal speed; evidently because its own air going ahead is always moved with equal impulse, and no one could offer a reason why this impulse should slow up.[329]

The fourth view is Aristotle's, that the air at B, set in motion by the man who threw the stone, is moved in front of the movable thing, and pushes on the air at C; and the air at C pushes on the air at D, and the air at D the air at E, and so on until it reaches G, which cannot move H, not being strong enough, and then when H does not get moved, it will not pull along the weight, and thus it will come to rest at G. So he talks in this fashion: a violent motion may be weaker because F is moved by E, therefore with a weaker impulse than E, and E than D, and thus a violent motion is always being weakened, as indeed experience makes plain. This too is not movement without something to do the moving,[330] because any part is moved &166 by the one before it, as F is by E, and E by D. Thirdly, the reason expressed is clear that any portion of the air ceases to be moved before it ceases doing moving: when D is moved by C, it moves E, because it is moved by C; therefore while D is at rest at E, D moves E itself out of its place, and so it stops being moved before stopping doing moving, the reason being that D stops being moved while D is at E, for then C is at D, because it was moving D. Therefore when C is at D, D is at rest at E, and then C is moved to F, and it is moved only by something else, which is D. Therefore D stops being moved before it stops doing moving. The reason is that while D is at C, it is not being moved but is at rest, and yet it does move E towards F. And if you object that a body does not move unless it is being moved, I say that that is true, but still the end of the first movement (the movement of the mover) is linked to the end of the second movment, though not the same, but what does the moving stops before what is moved, and this is because at any rate in nature[331] a thing that does moving is moved before it does moving. Hence a fourth thing is clear, that the movement of a thing that is projected is made up of an infinity of movements succeeding each other in turn, and is continuous *per accidens*; indeed, it occurs with the transfer of air B to C, air C meantime to D, and the air that was at D to E, and so with the rest.

Consequently such a movement is speedy too, because the ends of one are so linked to the starts of the next that it seems they must be transferred simultaneously, and this is not the case. But let us imagine ten oxen, &167 one in front of another, and all in front of a cart, and any of them having a goad on his forehead, which he uses to touch another ox on the back leg; then the cart will follow upon

[329] "remitti."

[330] "motor."

[331] "saltem natura."

the first movement, and this one will move a second one, and a second a third, and you will always see that any ox is moved by another before he does any moving, and yet the last will get moved almost at the same time as the first. This is because a series like this can only be made up of ten components, there being only ten oxen. But a succession of the air is made up of an infinity of components, and so occupies[332] a perceptible time from the start of a stone's movement till its end. But compression of the air is helpful for unlimited lifting,[333] as Averroes rightly said,[334] and it is itself the reason that motion got faster, and that it is unnecessary to imagine infinite motions, but only innumerable ones.

And this is Aristotle's view on the movement of things that are violently moved, a view grasped by no one right up to to-day.[335] But our need is rather for the first view, the simplest one, and one not involving such great difficulties. And when it is proposed that everything that is moved is moved by something, the proposal is very true; but what does the moving is an acquired impulse, such as heat in water, heat which is channelled there by fire contrary to nature—and yet when the fire is removed, it burns the hand of anyone touching it, and accordingly even an accident[336] violently attaching retains its power. &168 Let us state then for a start what is evident, and exists,[337] that there are four causes of violent prolonged speedy movement. The first is, that the moving cause does its moving speedily from the start. The second, that it does it over a large interval.[338] This is why the longer military equipments[339] are, the further the missiles go; and so the more a bow is bent for both reasons, the further it sends the arrow. For if it is bent up to B, the arrow will be moved with the bowstring alone from B to D; and if it is bent up to C, it will be moved from C to D. Hence if it is bent [393] up to C, it will be sent further in the proportion CD to BD. Again, with the string drawn up to C, it will return with a greater impulse to D than from B to D. Hence the arrow will be moved faster by the string than it will have been even after being shot. Nor need we add how strong may be the virtue that moves it, for all we need is that it moves it fast. But the cause that does the moving is strong, if it can do it &169 fast. For even if the cause were strong, but did its moving

332 "refert."

333 "Sed ad infinitum tollendum iuvat condensatio aëris,"—translation precarious.

334 Nenci identifies the source (208 n. 137).

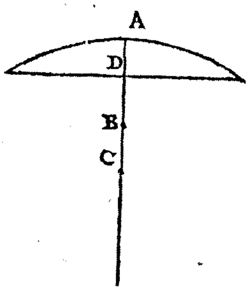
335 Duhem (*Système du Monde*, chap. 10, 8: 169–230) traces in great detail the history of the theory of the movement of projectiles from Aristotle onward. Clagett (*Science of Mechanics in the Middle Ages*, chap. 8, 505–25) advances the Duhem account, especially by adding details of Arabic contributions. See also Sorabji, ed., *Philosophy of the Commentators: Physics*, 348–56.

336 In the philosophical sense.

337 "quae sunt manifesta, et sunt."

338 "spatium," which can be of space or time.

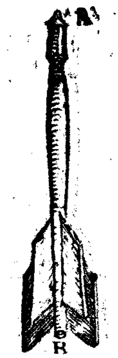
339 "machinae."



slowly, it would not be able to shoot far; in fact, nothing can move something slowly and far too, because what is moved slowly consumes a lot of time in its movement, and meantime[340] even the greatest power must be weakened while struggling against nature.

The third cause is the rarefaction of the medium through which the movement occurs; something can be projected fast in air, slowly in water, and barely at all in earth. And this is why those who attack enemy ships with artillery take great care to avoid the impact occurring below the waterline, although this would be more destructive; because the cannonball's impact is impaired by contact with the water, they prefer to hit the ship above water, but as low down as they can. The fourth cause of a fast prolonged blow is sharpness of the missile—it is less impeded by having a lesser amount of air in its way. Hence it is clear that the first opinion was truer than Aristotle's one on the cause of violent movement. For it is not so obvious why the sharper the projectiles set in violent motion are, the faster and further they are carried. Also, if any of these things are very close to the bowstring, but do not touch it although the air is moved, that air is no different from the air that precedes the arrow; this closest thing is not moved, anyway not enough to be carried far.

Furthermore, since air is soft, it cannot be thus violently &170 moved nor coerced together, hence it cannot move an iron ball either. And what is propelled by force will be no less moved in water than in air, though it is moved not only more slowly but much more slowly in water than in air. In the actual air, too, heavy things should be carried along no more slowly than light ones, if they are conforming to the theory of the vacuum. But these theories fail to show (since sharp things are carried along faster for this reason) that the primary air is moved with a greater impulse, and the rest is propelled by it in accordance with the same cause.[341] A missile is created for this reason, one that when projected always gets stuck in. The tip is A; the four large slender flights are located at right angles upon the spear BA. So when the missile is in motion, it cannot deviate, because one or more of the flights will meet the air head on. So when it is in motion, the missile BA will get stuck in straight. But if the power runs short, the missile will still fall straight and will stick in. And the reason for the invention of flights on arrows was the same. Thus the remaining considerations (apart from the last one) are evidence against Plato's view of antiperistasis, but not against his view of the air that is going in front. The last one has an obvious experience against it: in movement from rarefaction, a heavy ascent is more difficult than a light one, and consequently slower too.



340 "in quo."

341 The following five sentences first appear in 1554.

But &171 what creates trust in Aristotle's view is what he said, that a movement natural at its conclusion, one violent at the outset, one of things projected in the middle, gets more powerful.[342] Following Simplicius, Averroes (who had a corrupt text),[343] instead of "projectiles" read "animals." Though Simplicius had a good text, he failed to understand Aristotle, and by "projectiles" referred to "animals,"[344] because they were being moved to one side like projectiles—an absurd comparison and explanation.[345] This moved him[346] because he had said that violent things are already being moved more vigorously at the start, but natural things at the end; projectiles should fall into one or the other class. But he did not understand Aristotle. Since in fact projectiles were being moved by the motion of the air that was going ahead, and air is in itself mobile, the motion of projectiles is composed of a natural one to some extent and of a violent one; the natural one is bigger at the end, the violent one at the beginning. Consequently the motion mixed from these, which is the motion of projectiles, is most power-

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342 Nenci cites Aristotle, *De caelo*, II. 6, 288a19–23. The margin indicates "2. coeli. t.c. 35," and "in divisione Simplicii t. ca. 20." The original Aristotle (Loeb 170–71) says that all irregular motion has retardation, acceleration, and climax, and goes on, "ἀκμὴ δ' ἐστὶν ἢ ὅθεν φέρεται ἢ οἷ ἢ ἀνὰ μέσον, οἷον ἴσως τοῖς μὲν κατὰ φύσιν οἷ φέρονται, τοῖς δὲ παρὰ φύσιν ὅθεν, τοῖς δὲ ῥιπτουμένοις ἀνὰ μέσον."—"the climax may be either at the source or at the goal or in the middle of the motion; thus we might say that for things moving naturally it is at the goal, for things moving contrary to nature it is at the source, and for things whose motion is that of a missile it is in the middle." In the Latin translation cited by Nenci, this becomes, "Status autem est aut unde fertur, aut quo, aut in medio. Ut forte iis quidem, quae secundum naturam moventur, quo feruntur; iis autem, qui [sic] praeter naturam, unde; proiectis autem in medio." In Cardano's Latin, it becomes, "illud est quod dixit, motum naturalem in fine, violentum in principio, proiectorum in medio, fieri validiorem." The original Greek puzzled its Loeb translator, essentially because something dropped moves fastest at the end of its travel, something propelled against gravity moves fastest as it starts, but something projected can hardly be regarded as moving fastest in the middle of its travel. Mediated through the Latin translation into Cardano's Latin, it becomes no more comprehensible. Simplicius, *In Aristotelis de caelo commentaria*, *CAG* 7, 423. 6–36, in a Latin translation from Venice in 1544 quoted by Nenci, sheds little more light on the problem. Cardano, however, in what now immediately follows is more ingenious.

343 "depravatam literam textus."

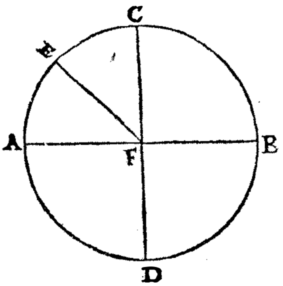
344 Nenci, 212 n.144, identifies the passage as Simplicius, *In Aristotelis de caelo commentaria* (434, 6–36) and supplies a 1544 Latin translation. See n. 342 above.

345 But this "being moved" means "moving themselves," and "animals" includes any creature with a soul ("anima").

346 "Movit hoc illum"—confusing to use "moveo" here in such a sense.

ful in the middle.[347] This theory is self-consistent,[348] and presents a resolution of the problem most beautifully. We do see that devices, scorpions,[349] and missiles projected by hand inflict more powerful blows at some distance than when too close and (so to speak) under the weapons themselves, or scorpions or devices. The reason is one that no one else can offer except the man who reckons that a movement is brought about &172 by this principle that Aristotle put forward: the air that is immediately behind[350] the start of a movement contributes only a little to the movement, but with the passage of time the natural movement of the air gets stronger as it is moved, and as it moves it opens up a little; hence the movement's speed must be increased by it, till it is starting less to do more moving[351] than it is suited for by nature.[352]

So, with the basis of violent movement understood—how things travel along that do not do so of themselves—let us show, with this made our starting-point, that heavy things that are moved by some impact and not according to nature have three components from which the movement is made up: their own heaviness, by which they are carried downward, the natural force of the medium as it is moved along, and the acquired power by which it moves another part of the air. So now let AB be a line &173 parallel to the horizon, which CD is to cut at a right angle, so that CA is equal to BC, and let AC be divided equally at E, which needs to be moved to F, and it is evident of [394]itself that it is deflected



by a very powerful blow towards D, because it is carried towards D by the impulse of the thrower and at the same time by nature. It was reasonable that the weakest impact would be the one contrary to that (i.e. towards C), and the most powerful one that of higher things[353] towards D, neither of which is established by experience; but the most powerful is that of the higher things FE, the medium one FC, and the weakest FA. Why so? Surely because the air travels straight rather than to the sides, and so the weakest impact is from F toward A. The strongest on this theory ought to be from F toward C, but because the whole

[347] Nenci here, 212 n. 145, draws attention to the subsequent dispute between Cardano and Tartaglia on the theory of motion, in which Tartaglia on the whole gained the upper hand..

[348] "constans."

[349] A small type of arrow-shooting catapult, dating back to Archimedes; see E. W. Marsden, *Greek and Roman Artillery* (Oxford: Clarendon Press, 1969), 53 and elsewhere.

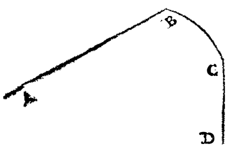
[350] "sub."

[351] "quoad plus movere minus incipit, quam moveri natura sit aptum."

[352] See nn. 319 and 327 above.

[353] "superiora."

heaviness[354] of the weight is resisting, the result is that where the air is moved most, and the weight possesses less heaviness[355] (i.e. along the line FE), is where the ball is hurled most powerfully. What remains is for it to be conveyed to a medium extent from F toward C, that is, straight up. However, do not go wrong about arrows, which travel at any time faster from F toward A than toward C, because of their length and their flights,[356] but never more than towards E. This is why those who make walls shake locate their artillery at half a right angle,[357] along the line[358] FE—the impact is increased by almost a third part. And when the ball has reached the top in a straight line,[359] it does not go back down right away along a circle or a straight line, but on a midway line, which almost reproduces a line &174 circumscribed round a parabola,[360] as BC is, and finally from C to D with the vertical motion of a heavy thing.



So things that are projected follow a path that consists of three movements: first a violent one, lastly a precisely natural one, and in the middle a mixture of the two. The basis of the movement being so multiple, measuring such things precisely is manifestly impossible, but may be approached by an estimate. Clearly the weakest movements are from B to C; hence balls of lead broken up by heat inflict even less injury for that reason, so that out of so many thousand people, you may see barely one or two wounded or severely struck, through impacts directed aloft, though often balls weighing more than half an ounce are regularly fired either to deal with birds or to unload a device.[361]

But since heavy things are moved with such difficulty along a line parallel to the equator, why is it that suspended things are so easily pushed along, so that a ring suspended by a thread may seem to be moved of itself, and consequently too

354 "gravitas."

355 "gravitas."

356 I.e. the feather attachments mentioned previously.

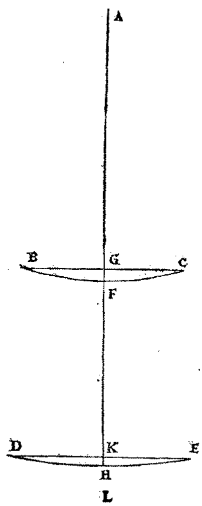
357 I.e. 45°.

358 "libella"—normally a plumbline, which would of course be vertical, not at 45° as here.

359 "rectà."

360 This insight of Cardano's, that part at least of the trajectory is a parabola, appears in the first (1550) edition of *De Subtilitate*, and is true, in the sense that in a vacuum the whole trajectory is a parabola. It is credited to him in *DSB*, and Caverni (*Storia del metodo sperimentale in Italia*, 4: 506–33) mentions Cardano and maintains that there were predecessors to Galileo, who is normally credited with demonstrating the parabolic shape of the trajectory in 1602–1604. In his *De Proportionibus* (propositions xc and cxvi) Cardano briefly mentions ballistic problems, but does not refer to a parabola. A. R. Hall (*Ballistics in the Seventeenth Century* [Cambridge: Cambridge University Press, 1952], 37 ff.) traces thoroughly the history of thought on the shape of the trajectory.

361 "machina."



presents the semblance of witchcraft?[362] The reason is that the whole &175 intact force is left to the person pushing;[363] a person who projects does two things: supports and impels. But with a suspended weight supported by something else, the forces available for pushing remain intact. However, when it is pushed, it returns to the middle with almost as much force as was used to push it aside. So since it was already pushed away from the middle, for instance over a distance of a cubit, by that force, it will have to deviate the same distance in the opposite direction, and so to come to rest very gradually, with unending to-and-fro motion.[364]

So when this movement in the ring[365] is slightly assisted, even by the invisible motion of breaths,[366] it is so much increased of itself that you would think that words had force.[367] Consequently, when the ring's movement is a little more energetic,[368] with it now moving itself, as I said, there seems to be a demon in the ring to move it. This movement is even easier with a longer thread, the proof being obvious: let the ring be at F, and be moved through BC, being suspended at A; and suspended again at A, let it be placed at H and moved through DHE, which is equal to BFC, and let L be the centre of the earth. Thus it is accepted that while it is at F, it will be moved through FG against its natural movement; and while it is at H, through HK, but HK is shorter than FG, as we showed in the first book on circles. So, since the moving power is the same, and what is moved is the same, and traverses a greater interval at F than at H, or &177 rises more from the centre, it will complete it[369] in a longer time. If it has to be moved in an equal time, it needs less impetus at H than at F; and so the higher up it is suspended, the more easily a bob[370] is moved, and with less work. Then as a long thread has been used, it will draw the starting of movement either from a heedless hand movement, or from the air, or from breaths[371] themselves, whose power descends even along the thread. So with its movement turning out so easy, and there being so many causes that move, it is

362 "praecantatio."

363 "impellenti."

364 "continuo ac alternato reditu"—this is of course a pendulum.

365 Or "in a ring," but the pendulum bob was specified as a ring just above, so I think it is the ring's movement that is meant..

366 "occulta spirituum motione."

367 Presumably the outflow of air during speech?

368 "concitatus."

369 The interval, presumably.

370 "mobile."

371 "spiritus."

unremarkable that the ring is moved by the beginning of the thread, even when the fingers stay still; and once that[372] is in motion, it will hardly be possible to find a beginning for stopping, for a heavy thing (as I said) when suspended moves itself so persistently. And this is how it seems to be moved by witchcraft.

But now that this is clear, someone will wonder why rarefied bodies not only accept rapid movement (which is in accord with reason), but even bring it about (which is not). For when it is inflicted on anything, the impact of water is less violent than that of air, and that of air is less violent than that of fire. For this there is the evidence of a weapon introduced I believe (I have not seen it) by a German, made of cypress and twenty ulnas[373] long, with an orifice so narrow that a chick-pea could not enter, even if it were round. The thickness is less than an ulna. It used to propel a [395]lead ball, quite small, but it fitted the orifice, with such impetus that it would smash through a plank. A reliable thing, without a bang and waste of powder: three advantages, but the same number of drawbacks: weight, size, and lack of power commensurate with its size.

&178 But if we set about attacking with fire, we need a much shorter and smaller weapon; in that case, fire propels more than air, and air more than water. The reason is twofold: that in an impact there must be moving, but also being moved. But we have shown that more rarefied things are very readily moved, and therefore with very great impetus. So they generate a great impact. The other reason is that what is rarefied can be greatly confined, because its density is far from the maximum. But when water has reached the density of earth, it can be got no further. So every device needs either to be large (otherwise it deals a weak blow) or to make a big noise; those that function with fire make the noise mentioned, in accord with the theory I mentioned; and those that function with air either are large, like catapults or ballistae, or else they deal small blows.

But people usually put arrows, not balls, on scorpions—not just because they are lighter, but also because with their point they augment the size of the impact. It is beyond doubt that a blacksmith of Brussels tempered a scorpion the size of a palm[374] wholly from steel, so well that he slew the debaucher of his wife with this weapon, by concealing it under a napkin. Thus he planned revenge for a vast injury, in safety and without a bang or suspicion;[375] in fact the smell of gunpowder usually gives the game[376] away. The same man set up a clock in the gem of a ring, a clock that was driven by a spring, and it used to display the hours not

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372 The beginning of the thread.

373 "ulnas" means "forearms"; an ulna according to *OLD* is "a poetical measure of length, apparently the span of the outstretched arms long." Later on, for Edward I of England (1305) an ulna (or ell) was very close to the modern yard (0.914 m).

374 On the length of a "palm," see n. at 1080 (1560) in Book XVII.

375 "sine strepitu ac suspicione"!

376 "insidiae."

just by an arrow, but by a thump.[377] This same man built a boat with marvellous craftsmanship, in which a woman used to beat upon a tortoise shell, and men used to propel the boat by the movement of oars through wheels placed underneath, like oarsmen rowing to a sea-shanty.[378]

&179 Even if these can appear mere fussy details,[379] still let me explain an invention of human technical skill, which derived its origin from the nature of air: I have decided to explain a beautiful instrument for the sieving of flour, invented less than three years ago, so that people can follow as I do so,[380] how it may be in order to match resources (so long as they are clever ones) to things of light weight. For though nowadays it is so handy that all millers possess one, he[381] gained a privilege from the Emperor[382] to prevent anyone possessing it without his consent, gained a livelihood from this trade, and so he soon built himself a house. And not only millers, but colleges of priests and of virgins dedicated to God, and various nobles that support a large family possess it, because of its outstanding convenience—I might say, its necessity. Numerous others, animated not so much by its convenience as by astonishment at it, have taken pains to make it.

And this is its structure. &180 There is a little wheel B, at the rim of which is a handle A which can be rotated. These two items protrude beyond the machine. In the centre of the wheel is a rod C, which is rotated by the wheel's motion, and it has two small wooden teeth positioned opposite each other, and another two close by, they too positioned opposite each other, but at a point intermediate to the others, so that when the wheel is turned once, it touches a broad piece of wood[383] four times, or rather the board[384] DE suspended on both sides of a small box.[385] In this way, as the wheel goes round, the board is kept perpetually in tremulous motion as it is touched by the teeth. Furthermore, the wood[386] C and

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[377] "ictus." "Very soon watches were so tiny as to be placed in the hilt of a dagger (Francis I of France paid a small fortune for two of these in 1518) or in a finger ring (Elizabeth of England wore one that not only told the time but served as an alarm: a small prong came out and gently scratched her finger). Some of these early miniatures were about as small as anything made since" (Landes, *Revolution in Time*, 87).

[378] "concentum"—it appears (http://www.traditionalmusic.co.uk/sea-shanty/0sea-shanty.htm, accessed 9 May 2009) that sea-shanties were available from the fifteenth century, so this translation may not be an anachronism!

[379] "parerga dicta."

[380] "simul."

[381] Presumably the Brussels blacksmith just mentioned.

[382] I.e. the Holy Roman Emperor.

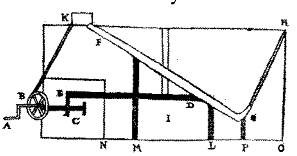
[383] "lignum latum."

[384] "tabella."

[385] "capsula"

[386] "lignum"—but C is a rod ("bacillus") previously.

a part of the table[387] are enclosed in a small box. Above the wood or table DE[388] is situated a flour sieve FG lying obliquely, and it is supported from G to H so as not to fall out. It consists on all sides of very thin—indeed, the thinnest and lightest possible—pieces of wood,[389] except in the middle where the flour gets shaken out of the sieve; as is usual, this part is made of linen cloth. Everything on all sides is kept enclosed in this receptacle,[390] and at its top lies the box[391] K, and in it a very light square dish, made for example of wood, in which the flour lies. It is held up in such a way that it can readily be shaken, and it is shaken by a rope attached to it from the other part of the wheel, i.e. the right hand one in relation to B. You recall also that the sieve FG is open from both heads: the top one, for receiving flour from the dish, the bottom one, to expel the bran from G. And the whole three-way receptacle is divided into LMN, with partitions set up from thin, firm, and entirely immovable boards. And if preferred, it can be divided four ways.



So with this arranged, when the wheel B is rotated, the rope shakes the dish, and the &181 teeth the board; the dish shakes out the flour into the sieve FG, the board shakes up the sieve. Thus the outcome is that the finest powdery flour[392] is shaken out first, and falls into NM, a part of the box. As it is vigorously shaken on its way down, another inferior and less pure part is shaken out into LM, and finally all the bran passes down into LO through the sieve's lower mouth G. Thus the three are assembled separately, the powdery flour in MN, the thick flour in ML, the bran in LO. And all the flour that flies about must return again to its place, so that nothing is entirely lost, since the box is not permeable[393] anywhere. And as you can readily see from the the theory itself, the sieve FG should not be too much tilted upward—if it were, the flour would reach to G and be ejected with the bran. Therefore if you have shifted the partition L right to the mouth of the sieve, or added another partition, as at P, and simultaneously you have bent the actual mouth G a little upward, you will not have made a loss of even an obol[394] of flour.

[387] "tabula," not "tabella."

[388] "lignum seu tabella DE."

[389] "tabulis," but see above.

[390] "capsa."

[391] "capsula."

[392] "flos farinae."

[393] "non transpirat"; the word "transpiro" is absent from *OLD*.

[394] Under this name there was the well-known small Greek coin, and also a Greek weight, one-sixth of a drachma weight. It corresponded to 0.72 g in the Attic-Euboic standard, and to 1.05 g in the Aeginetic standard [*OCD*].

Now appreciate the great advantages that follow from this device. First, that one man's labour fulfils the roles of three sievers, while he turns the wheel, and puts flour on the dish, and when the receptacles[395] are full, he assembles what has been sieved and the bran. The second one is that as the job is neither such hard work nor harmful, anyone can do it, and porters are reckoned of use, who are hired for a much lower wage than sievers. Thirdly, as all the flour is gathered and none lost, while [396] during sieving the motion of hands and arms means that gaps must open wide enough for arms to be able to separate, and &182 thus a substantial amount of flour gets lost. An additional point is that since the linen sieve shakes[396] on its own, it does not get so much worn—indeed, much less than when the flour is sieved by people; they have to shake the sieve vigorously, as they usually do. And it makes for economy that the flour is shaken out more precisely, so that the bran is perfectly pure. And all these without defiling the house and upsetting and disturbing the people. And with the device's characteristics[397] enabling it to separate a double or a triple flour, a feat impossible for sievers, except by guesswork that starts uncertain and then gets fickle.

But let us go back to the pulling ability of the air, now that the discussion of all violent movements is done. Thus we have now explained that air extends to heaven, and its purer part is called the ether. But neither ether nor air can be detected by the senses, because of the purity of their substance.[398] This has been arranged for the sake of animate creatures,[399] because if air possessed colours, things that are seen would look like that. For to anyone looking through green spectacles[400] everything looks green; in the same way, if air had a share of colour, everything would appear to be of that same colour. Similarly, if it had an odour, everything would appear infused with the same odour. Likewise, if it displayed a sharp or sweet taste, everything would appear sweet or sharp. In the same way, if something turns up hot, as occurs in summer, everything seems hot. On the same basis, too, night reveals the slightest sounds and noises, since by day the air is not entirely free of sound. So in order to be able to take on everything—tastes,

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395 "loci."

396 "tremat."

397 "natura."

398 This statement seems to pass by in silence the powerful palpable effects of winds etc.

399 Beasts and human beings.

400 The word used is "conspicilia," which in classical times meant "lookout posts." Spectacles were well known by the sixteenth century, but I have not succeeded in confirming this word for them. Cardano himself uses the very similar "conspicia" where it fairly clearly means "spectacles"; in his *De Immortalitate Animorum* (at *OO* 2: 483) is the tale of an old man of 94 who "literulas absque conspiciis legere consueverit," i.e. "used to read small lettering without spectacles."

odours, sounds, colours, &183 heat and cold, and all these as it is appropriate to reproduce them to the senses — nature has become free of them all.[401]

But when nature underlies primary qualities, it resorts to an opposite one, and the evidence for this is that the actual qualities of the things we have mentioned operate on their own; in winter, the air that is exhaled gathers into a rounded shape, since it is hot, and this is in fact due to the heat itself, not to the nature of the air. For cold air is not thus gathered, nor is hot air breathed into a hot environment. But why into a rounded shape? Because this is the most roomy one, and the strongest too, and also because it lays itself open to a cause of harm at a point only.[402] This is why those about to do battle, about to receive a blow, and about to shoulder a weight curl themselves all up into a rounded shape. Things that are launched from afar clash with greater impact; but those that are outside roundness are launched further away; they are further from the centre, which is regarded as a substitute for a fulcrum.[403] If air[404] is cut off, there is corruption of things possessing souls, but preservation of those lacking soul; unconfined[405] air corrupts things lacking soul, but preserves those possessing one. For air by its movement eats away things lacking soul, and therefore by ventilating the place corrupts them, but purifies and cools the heat of animated things.[406] But when confined and stationary, it keeps things that are remote from decay free of harm, because it lacks motion and so is not corrosive. But by staying still and hence decaying, it does corrupt, kill, and rot animals and things that can decay. Indeed, confined immobile air gets so much corrupted that when, in hopes of finding gold, the soldiers of the Emperor Marcus Antoninus under the command of Avidius Cassius[407] opened a small casket[408] in Babylonian Seleucia (they had found it in a &184 temple of Apollo), the emerging air had so much rotted that it afflicted the whole district with plague. Borne on the winds from there to

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[401] By night, presumably.

[402] "Quod ea cum sit capacissima, etiam sit robustissima, et etiam quoniam solo puncto laesurae causae se exponat;" — meaning not clear.

[403] The meaning is obscure.

[404] "hic" — masculine; refers presumably to "aër" which is mentioned several lines earlier, and is masculine.

[405] "liber."

[406] "animalia."

[407] This is not exactly what the Latin says ("cum M. Antonini Imperatoris milites Avidi Cassii . . . arculam . . . aperuissent") but the source called *Verus*, in *Historiae Augustae scriptores*, indicates that Avidius Cassius was the commander, and had captured Seleucia by treachery. The Emperor Marcus Antoninus is more usually known as Marcus Aurelius (Antoninus).

[408] Nenci (221 n. 150) has identified the sources here: Ammianus Marcellinus, *Res gestae*, 23. 6, 23–24, and *Verus*, in *Historiae Augustae scriptores*, 8. 1–2, to the effect that Roman soldiery released the plague of 167 A.D. by forcing open the casket Cardano mentions.

Greece, and then on to Rome too, it ignited the plague which devoured almost a third of the human race.[409] It[410] is also affected by metallic exhalations, and therefore it is kept in continuous motion by fans in the shafts of mines—otherwise it would put out lights and suffocate the people inside. So air is cleansed by movement, and reverts to its own pure nature.

On a similar basis, cereals enclosed below the earth pollute the air, and then are polluted in turn by it. And although because of the coldness of the air they are polluted later in Germany, here too after some years they are getting corrupted.[411] And for the same reason, they are preserved longer under the earth than above it.[412] But in France, with the ears of corn separated for many years in the centre and straw placed round them in a close array, so as to resemble quite a wide pillar, and a thatched roof[413] pulled over them of a safe thickness, they stay safe from animals and from the air itself, and are protected from water by the roof, and from germinating by the straw round them; actually all the seeds sprout at the place where they began, beans being an example. But[414] some of them seem safer in ventilated environments, not because air is preservative, but because when it is colder, it does not corrupt so much. In fact most ventilated things (especially in a lofty environment) are colder than enclosed things. Corruptions of the air also occur in consequence of earth movements; air that had lain hidden for many centuries and gets uncovered usually brings a great plague as it emerges. This is why serious pestilences commonly follow &185 great earthquakes. They also occur because of decays, great calamities, floods, and the death of locusts. These pestilences come from the air. But those that come after famine are of another kind. It is a remarkable type of plague; trustworthy authorities relate that at Constantinople (it used to be called Byzantium) a plague broke out which was of this kind, so that those suffering from it or threatened by the disease thought they were being killed by someone else, and they used to die in distress from this fear.[415] Meanwhile they could not see nor hear, but were driven out of their senses and

[409] This plague raged from 165 A.D. for 15 years, and killed two Roman emperors, one of whom was the celebrated Marcus Aurelius. Nine years later a second outbreak followed, causing up to 2,000 deaths daily at Rome. For further details see G. C. Kohn, ed., *Encyclopedia of Plague and Pestilence* (New York: Facts on File, 1995), 6–7; R. S. Bagnall, "P. Oxy. 4527 and the Antonine Plague in Egypt," *Journal of Roman Archaeology* 13 (2000): 288–92.

[410] The air, presumably. This sentence first appears in 1554.

[411] The tense is the present tense. These two sentences first appear in 1554.

[412] The thought is not clear.

[413] "tuguriolum." This sentence first appears in 1560.

[414] These two sentences first appear in 1554.

[415] The following six sentences first appear in 1560. This narrative is based on Procopius' account of the sixth-century Justinianic plague. See P. Horden, "Mediterranean Plague in the Age of Justinian," in *The Cambridge Companion to the Age of Justinian*, ed. M. Maas (Cambridge: Cambridge University Press, 2005), 134–60.

their minds as if thunderstruck or distraught. While they struggled with fever and cough, their warmth and colour still did not alter. Swellings kept appearing in various places, according to people's nature. In the end some were despatched by drowsiness and some by starvation. Through thirst, some too would throw themselves down wells. It is certain that there was a definite kind of abscess in the brain, since the disease was not being spread by contagion. What is certainly true is that there are practically as many modes of plague as circumstances.[416] Still, no pestilence rages for more than three years.[417] The reason is manifold. First, because if it rages for so long, it has almost no one left to vent its rage upon. Next, air being of very light substance, as people say, is incapable of any further decay; it was established above that what has rotted does not undergo further decay. In addition, [397]it is hardly possible that the air should not get moved in so long a time, and convey what is being corrupted across into the winds. It also appears that by God's goodwill some limit is set to all very evil &186 things; snakes do not appear to multiply beyond some limit, nor do acute diseases persist beyond the fourteenth day, nor can any severe misfortune last long. In the long slow sort of plague, no preordained limit is to be found—as in the case of the French pox, which it is now agreed has passed the fiftieth year from its onset.[418] And though this disease is endemic to the Indies, it is a pestilent contagion to us. We have written numerous books on this.[419]

Kinds of pestilence have the characteristics of poison from the air.[420] For some poisons are poisons by nature, such as those that are born,[421] and those of the worst of serpents. Some are poisons from decay, among which is the plague itself, and those that are made by technical skill, which were at one time called "cooked" and are now called "sublimed."[422] The strongest and fastest-acting are made by nature, which in every way triumphs over technical skill; but they are

[416] "tempora"—might alternatively mean "seasons."

[417] This is of course quite untrue; see for instance n. 409 above on the Antonine Plague. Scaliger (*Exercitatio* 32 [140]) comments that the term "rages" is apposite: milder plagues might be much more long-lasting.

[418] The following two sentences first appear in 1554.

[419] On Cardano's *De morbo Gallico*, see Maclean, *De vita propria*, M42, 67–68, and note that a single work such as this might contain a number of "books" (eight in this case.). But there are also references to its treatment elsewhere in his works; on this see Nenci 223, n. 152.

[420] "Genera pestis ex aere veneni habent rationem." The meaning might equally be "Kinds of pestilence from the air have the characteristics of poison."

[421] "nascuntur."

[422] N.B. in modern parlance, mercury sublimes on heating, i.e. evaporates without melting first, but as Castelli remarks, "*sublimatio* is a chemical term of ambiguous meaning"! It was much in use by alchemists, and details of the process are provided by Biringuccio (*Pirotechnia* 9. 2, trans. Smith and Gnudi, 352–53), who was highly sceptical of alchemy. See also n. 293 above.

scarce, the most common poisons being the work of technical skill, since in the devising of evil the human race is far worse than nature. So in a rare instance Nature was not ashamed to be defeated by men in these matters, provided only that the prize for magnitude remained with her:[423] people report that in Nubia (Ptolemy[424] calls it Marmarica[425]) there is a poison of which the weight of one grain of wheat kills a human being on the spot—ten of them during a quarter of an hour. Such a deadly power is on sale for a hundred gold pieces per ounce. As much as its selling price is expended for taxes. The purchaser swears &187 not to use the poison in the province—as if anyone who kills people of other districts was not a poisoner, or killing people was a less matter than perjury.[426] Will someone planning a poisoning be frightened of perjury? Is this the greater disaster, or is human folly? The state of affairs is worse with slow action than with speedy; the latter takes life, but the former takes away all hope and enjoyment of life. Theophrastus[427] relates that aconite is commonly prepared so as to kill in two months, three months, six months, a year, or even two years, and that the deaths depend on the times of harvesting the drug; with drug from an older plant, death takes longer; in fact they kept sowing the plant and gathering it. Alternatively, they did this because spring's gathering kills faster than winter's, as is also established for the powers of herbs, and of roots too.[428] And however

[423] The remainder of this paragraph with the following three paragraphs first appear in 1554.

[424] Claudius Ptolemy flourished at Alexandria between A.D. 127 and 148 and was an astronomer, mathematician, and geographer of enormous celebrity.

[425] The map of Girolamo Ruscelli (1562) can be viewed at http://www.raremaps.com/gallery/detail/13797/Marmarica_Nuova_Tavola/Ruscelli.html and shows Marmarica (a semi-arid coastal area) due west of lower Egypt, approximately from Derna to Sollum, while Nubia lies south of it. and southwest of lower Egypt.

[426] Leo Africanus is evidently the source here (Book 7, "Of the kingdom of Nubia"; trans. Pory, 3: 836; the version of Ramusio cited by Nenci [224 n. 153] is similar): "Heere is also a most strong and deadly poison, one graine whereof being diuided amongst ten persons, will kill them all within lesse then a quarter of an hower: but if one man taketh a graine, he dieth thereof out of hand. An ounce of this poison is sold for an hundred ducates; neither may it be solde to any but to forraine merchants, and whosoever buieth it is bound by an oath not to vse it in the kingdome of Nubia. All such as buy of this poison are constrained to pay as much vnto the king, as to the merchant: but if any man selleth poison without the princes knowledge, he is presently put to death." Dr Brown, editor of the Pory translation and with much nineteenth-century experience in Africa, does not believe it, and remarks (852 n. 32): "This story is apparently one of the legends told by the traders: for there is no poison known in Africa, much less in Nubia, which at all conforms to this description."

[427] Theophrastus, *Hist. Plant.* 9. 16. 4–7.

[428] "Vel quia collecta verno tempore celerius occidat quam hyeme, ut etiam de herbarum viribus tum radicum constat." The interpretation is not clear.

much the drug's time of action were prolonged, an inevitable and irreparable death was still looming over each victim in its time — a remarkable thing.[429] In a similar fashion, some poisons do not kill, but create a defect of some part of the body.[430] There was a spring beyond the Rhine, beside the sea coast, and its water caused loss of teeth in every one from the German army who drank from it. No remedy was found, except a herb from Britain.[431] And in the case of Caesar Taberna our fellow-countryman,[432] when after long torture by stomach pains he was dissected after death, a stone as big as an egg was found in his stomach. In fact poisons that kill over a period[433] cannot seek out the heart, brain, or bladder; for if they seek out the heart, they cannot postpone death &188 so long; if they seek out the brain, since they are far away, they will not kill—they can barely touch it. Only acute drugs damage the bladder, and kill fast. They can, however, do rapid harm, but kill slowly.

But the poisons that kill surreptitiously and after some time, so that the crime may go unnoticed, attack the lungs, the liver, or the stomach. Those that attack the stomach do so with pain[434] coupled with vomiting. Those whose target is the lungs, with wasting and cough. Those whose target is the liver, kill by destroying the blood, some by bringing about jaundice,[435] some by dropsy, most by vicious fevers. I have written elsewhere that out of thirteen men in the town Gallarate,[436] there were eleven who drank poison at a single meal, and they all died at various times, though some had even travelled to Rome and back in the meantime. Such a pretty discovery had been brought back from that town.[437] I will describe elsewhere some signs from which we can deduce that a person has

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[429] Theophrastus (*Historia Plantarum*, 9. 16. 4–7) does not say that death takes longer from an older plant, but that the poison is more rapidly effective the longer the time since it was gathered; also that those who survive longer die more miserably.

[430] "membrum."

[431] Pliny (*Nat. Hist.* 25. 20; Loeb 7: 151) runs: "When Germanicus Caesar had moved forward his camp across the Rhine, in a maritime district of Germany there was only one source of fresh water. To drink it caused withint two years the teeth to fall out and the use of the knee-joints to fail . . . A remedy was found in the plant called britannica . . . why the plant was so called I greatly wonder."

[432] "patritius"; the similar classical word "patricius" of course meant a "patrician."

[433] "ad tempus."

[434] This pain is "dolor iugi" and "iugi" may mean around the collarbone ("iugulum"), though this meaning is hard to establish.

[435] "regius morbus."

[436] Gallarate is in northern Italy, about 40 km northwest of Milan. It was Cardano's base for several years from 1533; see Wykes, *Doctor Cardano*, 58–63.

[437] Nenci (226 n. 157 points out that this event is also recorded by Cardano in his *Contradicentium medicorum*, lib. 2, tract. 5, contradic. 9, with more detail, but none to explain the curious term "tam pulchrum inventum" applied to the discovery of these properties of poison.

drunk poison, even though he feels nothing; but for the present I will introduce the more relevant[438] items. They are five. First, when a foul smell is sensed in food; or if no foul thing is present, a smell as if it conveyed a foul thing with it is sensed as foul. The same applies to horrible tastes. Pains too, without obvious cause, either in the stomach or the liver, or erosions of the bladder, or the sudden and spontaneous spitting of blood. A slow and deadly wasting is also an indication of poison having been drunk, and a great untreatable change of the body's colour.

But this is no place for debating diseases, but only the &189 more subtle lesson to be learnt in this discussion: in the absence of an odour or taste, one may happen to sense both, and this can be an indication of poison. The reason is that the melancholic humour reproduces such types[439] in lieu of the object—as too in the case of those bitten by a rabid dog, it happens to wander round their sight.[440] But it is particularly the poisons that act only in due course[441] which normally generate this black humour.

While I ponder these points, a significant doubt arises: since there are many poisons that can postpone death for years and still are poisons, may there be some that we use as food, and that still lead to death, though so late that they are not recognised as poisons? Because if there are such things, they will be just like items from the kinds of fungi. And as so many people are affected, in such diverse ways, at such diverse ages, with such diverse temperaments, life styles, skills, strength of powers, circumstances, and with such varied demise as they pass away, who could notice this mischief? Some country vegetables that we eat by chance act on a similar basis; very many of them actually remain hidden, and things that are tainted by a salamander and by toads or snakes. The chamaeleon plant[442] is an instant poison to pigs, wolves, and mice; who knows whether it may have a delayed action on human beings? In fact agents that do harm commonly kill after an interval of time. For sure, the mistletoe that grows from its root deals death to human beings. And what brings rapid death is to be classed as a delayed-action poison if it has been tempered.

Some of these can also kill by touch alone—if the saliva of a rabid dog drops onto a place wounded &190 in some way, or from which the top skin alone has been detached, it generally kills. Squill smeared onto the skin upsets the flesh, and cantharides held in the hand produces pissing of blood.[443] So what is surprising in a poison that kills by contact alone, and [398]particularly when we see that

438 "potior."

439 "species."

440 "circa visum errare contingit." The translation is speculative.

441 "temporanea."

442 Either of two plants: *Cardopatium corymbosum*, or *Atractylis gummifera* (the pine-thistle) [*OLD*].

443 I.e. haematuria.

a pestilence which has adhered to saddle cloths or a wooden board kills someone who has sat on either of these?[444] Some poisons develop only in the shade, like oleander and yew; some arouse poisons previously neutralised,[445] as twigs of cornelian cherry or sanguinaria[446] do; when these warm up in the hand, they bring back rabies in those who have been bitten by a dog and been freed from danger. In addition, people, and also beasts of burden, who have been flogged with rods of sanguinaria[447] are thought to suffer much. And snakes are alleged to kill, even through contact with the middle of a spear, as Mattioli[448] reports. Another man died on the spot after sucking the wound inflicted by a snake that had been cut in two. Others pass away from smell alone, like the one who dropped dead in public at Siena just through meeting his rival's odour. These cases look marvellous rather than really being so, whether one takes notice of human weakness, or the diligence of wicked cunning, or the power of things themselves, or the subtlety of the method. And as this[449] is the aim of our present undertaking, we will now disentangle it in three rather remarkable instances. Some things kill, as we said, at once on being swallowed, others by contact only, others by smell; it is unclear which of these is the more remarkable. But hear what their cause is, and you will be enlightened. If a spark of fire gets into the heart, are you not convinced that the person will die instantly? But poison is more violent[450] than &191 fire, as we will make plain when we come to discuss the most acid waters. A poison like this in potentiality becomes like this in actuality while it is in a body; so I say it will be lethal, and there will be less than a tenth of a wheat grain. In fact a spark of fire is less in weight and size and substance than the tenth part of that grain. Look, you are seeing a quite remarkable thing, how fast it turns out neither obscure nor uncertain: that a vapour received into the fastnesses of the brain kills by smell alone. As there is nothing to bar entry to the brain, and it draws in air like the heart, the vapour instantly ruins and destroys the spirit held in the ventricles of the brain. Such a poison has to be acute. I recall that I

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444 The remainder of this paragraph together with the next one first appear in 1554.

445 "extinctum."

446 This word is identified as knot-grass (*OLD*) in Celsus etc., and as of use for arresting haemorrhage; here the point may be that it can be applied to do damage.

447 On sanguinaria see n. 446 just above.

448 Pietro Andrea Mattioli (or Matthiolus) (1500–1577) was an Italian artist and botanist, especially celebrated for his commentaries on Dioscorides (Venice, 1544), embellished with 500 engravings and augmented by his own observations, which ran to some sixty editions, and for his translation of Dioscorides into Latin (1554). See *Dictionary of Scientific Biography* 9: 176–80, and K. M. Reeds, *Botany in Medieval and Renaissance Universities* (New York: Garland, 1991). Nenci (228 n. 161) has traced the reference here.

449 Apparently "this" is "the subtlety of the method."

450 "acutius."

was so terrified of the odour of certain things that I regretted having smelled them, yet such things were far from the nature of poison. This happens in everything that is collected by distillation with fire, if it was already hot of itself. And decayed things are not without risk. It has been demonstrated, indeed, that they are enemies to our nature; and that things that are being distilled have a power with a share of fire, and also of the substance and heat which thrive in the thing being distilled. So what is there remarkable in a human being being suddenly slaughtered by an odour alone? There is also experience of touch doing the same, and even not direct touch, but touch through a spear—and to tell the truth, this is more difficult and remarkable. But let anyone turn his mind to these three things: fear in a number of people (for not everyone is equally affected); and the power of the electric eel, which can numb a person's hand even via a net; and the breath[451] that emerges from a snake's mouth, since during pestilence we see many people perishing from &192 this alone. Let him gather all these three together: many people perished from deadly breath alone, many from fear alone, many felt numbness of the hands through touching a net. Then when a snake has been injured, what is surprising about the fear and the deadly breath and the contact producing sudden death? No, the really odd thing is that this is so uncommon. Therefore what nature does of herself, technical skill can produce with more cunning and success, when contriving evil.

But you will ask why it is then that few die like this—the causes are numerous. Firstly, a few people refuse to employ this; princes dislike[452] methods which others could use against them themselves. In addition, there are not many people acquainted with them; sensible[453] people prefer not to follow an abominable example, and incompetent ones cannot. Furthermore, what sane person would deliberately handle such a violent beast? These poisons also can only do harm when given in large doses and all of them takes hold. But princes are on high alert against these things. There is also a very grave peril for traitors, if their plan is evident not just from their intended victims,[454] but also from their own patrons,[455] in case they have a witness to their crime after its commission. In summary: those who have been well brought up by nature or by skill[456] prefer to dispense with this knowledge, which only makes for man's destruction. As I was quite curious about everything a human being might properly know, I regarded

451 "spiritus."

452 "odio habent"—the phrase in this sense is post-classical, and classical Latin does not employ precisely the same phrase, using either "in odio esse" or "odium habere," each of these meaning "to be hated," not "to hate."

453 "sapientes."

454 "ab his, in quos moliuntur."

455 "ab his propter quos . . ."

456 "arte."

ignorance of this alone as in lieu of excellent knowledge,[457] and I never enquired into it, nor would have wanted to possess it if anyone had deliberately put it in my way. But rather, if anything needed elucidation, I moved into getting assistance and taking care.[458] Getting assistance therefore means not sticking &193 to some position until one's hand warms up; frequent washing of the parts with cool water; also anointing with some oil flavoured with rue, not the common oil, but oil made in the same way as cosmetic-makers[459] make aromatic perfume[460] and clove oil.[461] I also said that fire applied to the spot quenched all poison;[462] but in fact fire quenches some poisons and exacerbates others. It always quenches while being applied to the spot, since its virtue removes all moistness. But all dryness resides in some moistness; we see that manifestly dry things have no powers. And there are manifestly dry things that lack the nature of mixed things and of elements. Indeed, all elements, as I said, are moist. And a mixed thing is mingled because it is moist. Fire, then, applied externally, and anything very internally hot, restricts[463] all poisons. But very hot things applied internally are themselves poisons. It[464] exacerbates some things; Nero flogged Locusta, a manufacturer of poison, because it[465] had not killed instantly.[466] She cooked it again (people used to refer to something being "cooked," which now we call being "sublimed" or "distilled"). So a fire enhances the powers, if they are being mingled, with the blowing off of more rarefied moistness, in which the poison's power resides. But if pure things are distilled or poisons are being mingled with poisons, it exacerbates the poison; similarly in the case of medicaments, something is added for penetrating, and though it should reduce the power, it increases it.

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457 "optimae scientiae esse loco."

458 "ad auxilia et cautionem traduxi."

459 "pigmentarii."

460 "spicatum"; *OLD* identifies this word as "a flower with spiky inflorescence"; Castelli equates it with a costly aromatic oil otherwise called foliatum, and it is mentioned by Galen: "quod praestantius nardino unguentum sit, nempe foliatum, praeterea quae spicata vocant, quae ventrem et roborare possunt, et calefacere (νάρδου κρεῖττον χρίσμα, φουλιάτον τε καὶ τὰ καλούμενα σπικάτα)" (*De sanitate tuenda*, 6 chap. 10; K. 6. 427).

461 "garyophylatum."

462 The remainder of this paragraph together with the next two and the first two sentences of the next first appear in 1554.

463 "finit."

464 What "it" is is unclear; the verb is singular.

465 Or "she."

466 Tacitus (*Annals* 12. 66–67) recounts how Locusta, a professional poisoner and long retained as part of the stock-in-trade of absolutism ["inter instrumenta regni"], was hired by Agrippina the Younger to poison the Emperor Claudius, and had a tough battle to complete the job, as outlined by Cardano here. Nero later had Locusta flogged, but subsequently rewarded her for expertise at poisoning (Suetonius, *Nero*, 34) and ultimately she was executed by the later Emperor Galba..

But let us move on to remedies.[467] First comes the drinking of theriac[468], and if it is reliably prepared, everyone knows how much it helps. Secondly, the mouse that people call moisis;[469] they say it feeds on napellus root, whether napellus is aconite or something different;[470] &194 but this will be discussed in its proper place. Some quite reliable people report that they have seen it. But it would have been worth their telling us how such a small creature could dig in the earth, and with what extraordinary eagerness[471] it makes its way to that food, in such quantity and for easier eating.[472] And although all animals perish instantly through eating aconite, this mouse, weaker than the rest in its smallness, softness, brief and restricted life span, could become able to adapt to such an acute poison. But if this occurs, it has been shown that everything that feeds upon poison is an antagonist to poison[473] or resistant to it; it will be an excellent medicament for poisons. People say there has been one discovery, that there are large flies that

[467] "auxilia."

[468] On theriac, see G. Watson, *Theriac and Mithridatium* (London: Wellcome Library, 1966), and especially P. Findlen, *Possessing Nature* (Berkeley: University of California Press, 1994), 241–47 and 267–86. In sixteenth-century France and Italy, it was prepared at public ceremonies, and in Italy there was a previous catching and killing of vipers, a crucial ingredient in the multi-component mixture. An especially authentic theriac was prepared in Italy in 1561 and 1566 (Findlen, *Possessing Nature*, 274). In mid-century Paris a scare about fatal poisonings occurred so severe that "people were afraid to eat or drink, and resorted to Mithridatium and theriac and remedies like unicorn's horn and bezoar stone," which must have rendered proper nutrition difficult. The modern word "treacle" is derived from this word for a therapeutic mixture of variable composition and potent reputation; viper flesh and opium were among the required constituents. Theriac is mentioned in the *De abditis rerum causis* of Jean Fernel (ca. 1497–1558), one of the most notable physicians of the late Renaissance in Paris, see Forrester and Henry, *Jean Fernel's On the Hidden Causes of Things*, 75, 175, 185, 499, 587, and 733, but not in his *Physiologia*. Marsilio Ficino (1433–1499), the Renaissance Platonist, advised regular administration once or twice a week to maintain health (*Three Books on Life*, 139).

[469] The word is used by Matthioli, as Nenci (213 n. 163) indicates, but is not otherwise identifiable.

[470] The Latin word "napellus" is a diminutive of "napus," a turnip, and here refers to the shape of the root of "monk's hood," *Aconitum napellus* L. Another name is *Aconitum lycoctonum*—"wolfsbane." André (*Lexique des termes botaniques*) mentions that its French name is *Navet du diable*. It cannot be distinguished confidently from the "aconite" next mentioned, of which various varieties exist. Dr Robert Mill, of the Royal Botanic Garden, Edinburgh, kindly provided help with this botanical identification.

[471] "affectus."

[472] "in eum cibum in tanta copia facilioreque alimenti"; the syntax is elastic.

[473] "alexipharmacum." The word means "Antagonist to poison." Preparations of this name date back to Galen (see for instance *De simplicium medicamentorum facultatibus*, 5. 18; K. 11. 761–64) and Hippocrates, and their composition and uses became diverse. Also mentioned in Book VII at 473 (1560).

eat it. If this is the case, they use the leaves or the flowers, [399]none of which is as poisonous as the root is. Then flies do not cling much, nor tightly. However, people mix a counted two dozen of these flies with Lemnian earth[474] and laurel berries and mithridatum,[475] and make a health-giving medicament, of weight equal to all its ingredients. If they do no other good, the mithridatum, Lemnian earth, and laurel berries oppose the poison, and the flies stimulate vomiting. But if it is true that the mouse feeds on this, the mouse's power will be great. There is nothing to prevent mice being prepared with skill, after being gradually brought to this with cheese and flour, juniper and laurel berries.

The third medicament is made from blood, especially storks' blood. It has been shown that this is the supreme protection against poisons. In fact everything that feeds on a particular food, provided the food is intact, holds on to its special power complete; when it has passed &195 into the food, it takes on the nature of the creature that is nourished.[476] Even so, it does hold on to something of its previous nature. For the bodies of creatures that feed on birds are hotter than those of fish-eaters, and those of garlic-eaters are hotter than those of lettuce-eaters.

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[474] Lemnian earth enjoyed a therapeutic reputation from antiquity. Galen travelled personally to Lemnos in A.D. 168 to obtain genuine Lemnian earth (*De simplicium medicamentorum temperamentis et facultatibus*, 9. 1; K. 12. 171–75). On this, see V. Nutton, *Ancient Medicine* (London: Routledge, 2004), 245, and especially F.W. Hasluck, *Christianity and Islam under the Sultans* (Oxford: Clarendon Press, 1929), 671–88. The earth was compressed into tablets ["sphragides"] impressed with the stamp of the priestess of Artemis to warrant their genuineness. The need for care to secure the genuine article was still present in 1721, when doubts were mentioned in the *Dictionarium medicum* of Castelli. And towards the end of its vogue, its traditional properties were summed up by Francis Adams, the translator of Paulus Aegineta [3: 83], in 1847 as "moderately desiccative and astringent, an antidote to deleterious medicines, cures malignant ulcers with wine or vinegar, stops all kinds of hemorrhage, and removes dysentery and spreading ulcers of the intestines, the gut being first washed out with an injection of honied water, and then of brine." Of the "deleterious medicines" or poisons amenable to Lemnian earth, Jean Fernel (*De Abditis Rerum Causis*, Henry, Forrester trans. Bk. 2, chap. 17, 693) mentions cantharides and sea hare, which Cardano in the present work (190 [1560]) says are treatable with Armenian earth. Currently a group from the Department of Archaeology at the University of Glasgow are investigating the possibility that clay from Lemnos contains a therapeutically active component, "probably an antibacterial and astringent alum group salt of the type used in modern pharmaceutical applications." See A.T. Hall and E. Photos-Jones, "Accessing Past Beliefs and Practices: The Case of Lemnian Earth," *Archaeometry* 50 (2008): 1034–49.

[475] Totelin (*Mithradates' Antidote*) provides a detailed account of the history of mithridat(i)um. See also n. 468 above. A now somewhat dated but extensive and valuable account of these preparations is provided by Francis Adams in his commentary to Book VII section 11 of the works of Paulus Aegineta.

[476] "cum vero in nutrimentum transivit, naturam acquirit eius quod nutritur." The meaning is unclear.

But when a food needs to be nourishing, it passes into blood in mid-travel.[477] There is in fact a greater alteration from blood into the substance of the organs[478] than from food into blood, whether you have taken account of duration, or of amount of change,[479] or of what intervenes.[480] If then in a complete alteration the whole of the previous power is not abolished, then at half time and when the action is half over, it will retain half its powers. So the blood of a hen fed on snake flesh, and much better, that of a stork or crane, since they naturally feed on this and are altered without corruption,[481] is intermediate between the nature of poison and that of a stork. And an "alexipharmacum"[482] is what is intermediate between poison and our own nature, a nature which is consistent with the nature of a stork because each of these two animate beings[483] is a thing with blood and complete.[484] So a medicament made from blood provides prompt aid against poisons. It is worth using not only storks but also ducks, because they consume scorpions and toads. There is an additional reason, that the blood in storks is besides of a kind that is unaffected by poisons,[485] and consequently retaining a similar power within our body, renders our body less vulnerable to poisons.

We will deal later on with the stone and other topics, but the major point is that there is an oil which when smeared on the arteries cures poisoning. This is not what we have just been speaking about, but of a different kind. But now that we have got involved in these discussions, I reckon it &196 relevant to look into this: how an oil can be prepared so that when smeared on the arteries, it makes the poison be expelled by vomit or diarrhoea or sweat or urine. It surely should be metallic, which must be the most potent. At one time I saw something like this, and concluded from its weight alone that it must be metallic. And from the nature of poison it should be so, for by excessive heat (as people put it) it destroys the evil power previously taken in, and by its resemblance it summons out what is doing the damage, and expels it by contrariness. There should be a good deal of dispersing power in it, and in addition a certain contrariness against the poisons themselves, two features appropriate for the juice of asafoetida.[486] So things

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[477] This means a Galenic one-way trip carrying nourishment to the tissues, and there is no allusion to circulation of the blood.

[478] "membra."

[479] "differentia."

[480] "media."

[481] The sense is unclear.

[482] The word means "Antagonist to poison." See n. 473 above.

[483] Stork and human being.

[484] "sanguineum atque perfectum."

[485] "non a venenis patiatur."

[486] Cardano here uses the phrase "succus laseris" which became known subsequently as asafoetida, and was regarded by Basil Valentine as the Universal Remedy [Castelli]. "Laser" is the plant *silphium*, "laserwort, *Ferula tingitana*," frequently mentioned by Galen (see Durling, *Dictionary*, 290). Another source available to Cardano (Pliny, *Nat.*

that have to expel a poison must be metallic poisons, but not very harsh, and very hot and dispersing, and in some way contrary to the poisons. So their matter can consist of the following: Mysis,[487] orpiment,[488] and asafoetida, and gentian, and fat of venomous snakes, and aconite; if a number of these are present in any earth, the oil extracted from it by the power of fire will be outstanding, very safe, and a thing that expels by vomiting.[489] Overall, they need to be metallic, strong, and smeared on. The evidence is the earth that pedlars bring in from the island of Malta, which works against the bites and strikes of snakes—though there are some who say they have discovered that an oil made from scorpions, sulphur, and also chamaelea[490] and St John's wort delivers from poisons and plague when smeared on. They gather the &197 scorpions alive and very large, at the time of the Dog Star, because then this creature is very dry, as also are all the rest of them. As we shall explain, poison is established in snakes through dryness. So people warm them up in a frying pan with fire placed on it until they sweat, and thus the oil poured over absorbs their sweat. But there is also in this oil a metallic sulphur. If then the oil is acquired from that island of Malta, it is abundantly clear that it is of use against most poisons, as it needs to be metallic, and endowed with poison, features which resist poisons. What in fact purges poison needs to be poison in substance, as it were; for instance, when rhubarb does not purge bile, it is turned into bile.[491] It is in substance the sort of thing that can be turned into bile.

Hist. 19. 15) however defines these words differently, saying that laser is the *juice* of *silphium*, *silphium* being for him the Greek equivalent of the Latin *laserpicium*, and discussing its properties at length. *Silphium of Media* was, according to Dioscorides, *Ferula assafoetida*, asafoetida.

487 This may be the "misy" mentioned by Pliny (*Nat. Hist.* 19. 12), who says that it grows in Cyrene and is sweet in scent and flavour, but fleshier than truffles ["tubera"]. Castelli is of no help, offering "μύσις vide *Myce*" and the latter seems to mean for him "a shutting up," from μύω.

488 "Orpiment" is in fact a corruption of "auripigmentum"—"gold colour"—because it is indeed of a fine yellow hue. It is arsenic trisulphide. Cardano provides further information on it in Book V at 384–85 (1560).

489 The following seven sentences first appear in 1554.

490 I cannot trace any item of this name, apart from the present-day *Chamaelea gallina*, a kind of clam (the bivalve mollusc). Chamaele*on* is the animal, and also (according to *OLD*) one or other of the plants *Cardopatium corymbosum* and *Atractylis gummifera* (pine-thistle).

491 The thought is not clear; there is a marginal reference here reading: "Explicatio sententiae difficillima 5. de simplic. medicamentis cap. 18," and indeed in Galen (*De simplicium medicamentorum temperamentis ac facultatibus*, 5. 18; K. 11. 761–64) an oblique statement is found, and no mention of rhubarb.

But someone will wonder how it is practicable to expel a poison just by anointing the arteries, and whether this is the ideal approach.[492] By Hercules, I would not call it ideal, with this feeling, that if over and above it you put in the draught[493] either theriac,[494] or milk, or juice of nux vomica[495] gathered with fire (this juice resembles water in its colour, but not in odour nor taste) or anything else you have better, like the antidote which some pedlar used to sell against poisons while I was correcting this book, he would indeed be making better progress.[496] I would dare to put it neatly[497] thus: anointing of the arteries and external applications are more excellent and potent than things drunk, with just this one exception: that the poison still remains in the stomach. Then for those[498] that bring on powerful vomiting, milk, a powder, &198 oil, water of nux vomica (which we have just called "juice") are outstanding.[499] It follows that in cases of poisoned bites, stings,[500] poisoned ointments, poison drunk which has in that way reached the precordia,[501] external applications are more effective. And so some people customarily[502] insert themselves into eviscerated living mules; that heat summons the poison forth, and destroys its evil intent. A poison also kills through its power reaching the heart; but applications that are smeared on reach the heart with their faculties practically intact, and very quickly too. Poisons that are drunk (except those that penetrate slowly and are followed by a long delay) pass first in the stomach, then in the veins adjoining the liver, then in the liver,

492 "praestantissimum."

493 "in potu."

494 On theriac see n. 468 above.

495 "Nux vomica" is not included in *OLD* nor *L&S* nor Castelli. Nowadays it means the dried seeds of *Strychnos nux-vomica*, which contain strychnine. Vomica on its own means an abscess, as e.g. in Fernel, *Pathologia*, Bk V chap. 10 (279).

496 "ut quod forsan quidam circulator adversus venena vendebat antidotum dum haec emendarem, quin etiam melius proficeret." Syntax tortuous and meaning uncertain.

497 "bene."

498 Apparently poisons.

499 While the sense is unclear, perhaps these agents would moderate the effect of an emetic poison still present in the stomach.

500 "aculeorum ictibus."

501 The word means "what is in front of the heart," and its meaning for Jean Fernel may be deduced from a passage in his *Physiologia,* Book I chapter 7: on the limits of the "lower belly": "utrinque per cartilaginosa costarum extrema (hypochondria Graeci vocant, nos praecordia) ad ilia et inguina tandémque ad pubem porrigitur." In other words, it means the ends of the costal cartilages, below the sternum. For Cardano, a vaguer meaning may be suspected; and in classical times, it had other and less specific meanings; see R. B. Onians, *Origins of European Thought* (Cambridge: Cambridge University Press, 1951), 40–42.

502 "solent"!

finally also in the right side[503] of the heart, and are so blunted in their powers that hardly a trace remains at the time when they ought to be maximal. Thus, in the case of quicksilver (discussed in the treatise about the Indian lues),[504] scabies, psora,[505] and the Indian lues are driven out by the evil and harmful heat, since it makes its way in by subtlety and weakens and drives out by its heat. On the same principle as in the case of poisons, things smeared on are conveyed promptly through the arteries into the [400]left chamber of the heart. Experience in the Indian lues (where it pushes away even the bones, if expedient)[506] shows that even like this, they can alter the whole body, and move, change and eject all the humours.

But you will say, too late:[507] "Because this is not reduced to the form of a thin oil, but the actual substance of quicksilver is used, we cannot apply it to the praecordia as we do in the veins."[508] Galen explained the fashion in which agents smeared on the arteries are conveyed so quickly &199 to the heart, in approximately the following sequence of words: "The air that surrounds our body makes its way in through the body's loose structure."[509] For while the breath is exhaled from the heart through the mouth, the air flowing around from the pores of the arteries is seized in its place, and there occurs (though not at the same time) a twin inspiration—one from the mouth, the other from the arterial pores, as it were reciprocally.[510]

It is thus accepted that agents smeared on the arteries, whether they are poisons, or treatments for poisons, or agents that propel poisons, are ingested[511] by the heart with similar impact, and stick there firmly. But mercury is sucked in by the human body with such vigorous force that in cases of ulcers on the head,

503 "sinu."

504 About 1537–1538 Cardano wrote a work entitled *De morbo Gallico—On the French Disease* (Maclean, *De libris propriis*, M42, 67–68). There is a marginal ref. here to "Lib. 4 cap. 1" which is definitely to that work; Nenci, 236 n. 171, here refers. It is unclear how it acquired the altered title *De Indica lue* in the text adopted by Nenci; however, a section of the work is on treatment with guaiacum ("lignum Indicum") and this may have engendered confusion; the same phrase recurs twice just below in the present work.

505 Castelli identifies these two itchy skin conditions as one and the same.

506 "ubi etiam ossa si expediat propellit."—meaning obscure, and the subject of this clause is not clear.

507 "serò," which might mean "too late" but possibly means "on reflection."

508 The following three sentences first appear in 1554.

509 "raritas."

510 The sequence of words is certainly "approximate," at the reference "8 De doctrina Hippoc. et Plat. cap. 80 [for "80" read "8"] supplied in the margin, but Galen does say (*De doctrina Hippoc. et Plat.* 8. 8; K. 5. 711) that when the chest and lungs have breathed out their breath, the place is refilled from the air round the body, which works its way in through the more rarefied flesh.

511 "hauriuntur."

it drips out from the mouth like drops falling from a container,[512] although it had been smeared on the arteries of the hands and feet after being crumbled and quenched.[513]

The sequence of thought[514] has dragged us too far away from the aim of our discourse: we were actually trying to demonstrate that the air is always in motion in the locations where it is free, and is therefore in a higher region, drawing the evidence from this, that when at rest it decays. And from that point we fell into an account of the plague, and were not recalled, but rather slipped into an enquiry about poisons; it was not valueless, but as I said, we have strayed far from our aim. So my pen must be summoned back to the motion and stillness of the air. Solinus recounts that Olympus, the mountain in Thessaly, rises so far upward that when the sacrifices have been completed on the anniversary day, the ashes stay motionless until the subsequent sacrifice, because the &200 top of the mountain is so high as to be wind-free for the whole year.[515] But if this is the reason, why does the same thing not occur in the Caucasus mountain, which separates the Albanians[516] and Colchis from Sarmatia?[517]—Aristotle reports that it is so lofty as to be visible from the mouth of the Maeotian marsh, and on its top it shows the Sun with rays illuminating it up till the third part of the night.[518]

512 "pyxis"; Castelli indicates that this signifies various types of container.

513 The Latin of this sentence is absent from Nenci's edition (237).

514 "continuitas."

515 Gaius Iulius Solinus was a Roman geographer who probably lived soon after A.D. 200, and was author of *Collectanea Rerum Memorabilium*, a summary of the origins, history, customs, and products of parts of the known world. He derived his material almost entirely from Pliny and Pomponius Mela. About Mount Olympus, he wrote that "ara est in cacumine Iovi dicata, cuius altaribus si qua de extis inferuntur, nec difflantur ventosis spiritibus nec pluviis diluuntur, sed volvente anno cuiusmodi relicta fuerint eiusmodi reperiuntur: et omnibus tempestatibus a corruptelis aurarum vindicatur quidquid ibi semel est deo consecratum" (ed. Mommsen, 68. 8. 18; this points out the derivation of the tale from Pomponius Mela, 2.2.10).

516 This Albania is not the European Albania of to-day, but lies south of the Caspian Sea, within the present northern Azerbaijan and Daghestan, and was conquered by Pompey the Roman in 65 B.C. Colchis lies on the east coast of the Black Sea, and its mythical history as the destination of the search for the Golden Fleece is summarised in the *Oxford Classical Dictionary*, with its later history.

517 The Sarmatians in the time of Herodotus lived between the Caspian Sea, the Don River, and the Sea of Azov, and were dominant there until the third century A.D. They are mentioned too by Strabo (*Geographia*, 11. 2. 15–17, cited by Nenci, 238); also see Book XV at 728 (1560).

518 Aristotle, *Meteorologica* (I. 13, 350a28–33; Loeb 97): "The Caucasus is the largest mountain range, both in extent and height, towards the summer sunrise [i.e. the northeast]. A proof of its height is the fact that it is visible both from the so-called Deeps [Loeb translator mentions the "so-called unfathomable deeps of Pontus" on the northern coast of Asia Minor, to which Aristotle refers at 351a11] and also as you sail into Lake

Though the theory of the sphere does not permit this, I would not deny that it is an extremely high mountain, and on the same reasoning, what was said about Olympus should fit it too. The same will happen for the mountain in Tenerife. This island is one of seven which Ptolemy[519] called the Fortunate Isles,[520] beyond the Columns of Hercules.[521] For if it is right to believe this, people say it rises to 60 miles,[522] and with a tip in the shape of a diamond.[523] In Beregua too there is one of 50 miles, and in Gaira the mountain tops are covered with snow, although it is only ten degrees[524] distant from the Equator. Both these provinces lie beside Paria.[525] There is another mountain in Mauritania Tingitana,[526] a province of Africa, which was once called Solis on account of its height, but is now called Hanteta by the inhabitants.[527] Again, there is an exceedingly high mountain in

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Maeotis [the Maeotian marsh or sea is now the Sea of Azov, which opens into the north of the very much larger Black Sea]; and also that its peaks are sunlit for a third part of the night, both before sunrise and again after sunset."

519 See note 424 above.

520 The Islands of the Blest (*Fortunatae insulae*) were originally, like the "Gardens of the *Hesperides*," the mythical winterless home of the happy dead, far west on Ocean shores or islands (Hom. *Od.* 4. 563 ff.; Hes. *Op.* 171; Pind. *Ol.* 2. 68 ff.). The islands were later identified with Madeira (Diod. Sic. 5. 19–20; Plut. *Sert.* 8) or more commonly with the Canaries, after their discovery (probably by the Carthaginians). The Canaries were properly explored by King Juba II (*c.*25 B.C.–*c.* A.D. 23), who described apparently six out of the seven. Ptolemy regarded them as the westernmost limit of the world (see Ptolemy per Shastri in Bibliography). Pliny (*Nat. Hist.* 4. 119) said they faced Cape Finisterre, and provided much further detail at *Nat. Hist.*6. 202–5.

521 The Straits of Gibraltar.

522 On the mile, see n. to 34 (1560) in Book I..

523 The celebrated height of Tenerife prompted the poet John Donne (1572–1631) to write how the Moon might foul it:

" But keeps the earth her round proportion still?
Doth not a Tenerife or higher hill
Rise so high like a rock that one might think
The floating moon would shipwreck there and sink?"
(*The First Anniversary*, 285–288)

524 "partes"; *OLD* gives a degree as a valid meaning for the word "pars," citing Vitruvius and Pliny.

525 See n. 687 below. The following two sentences first appear in 1554.

526 "Tingitana" means connected with the modern Tangier, and this province was originally established by the Roman Emperor Claudius (*OCD*).

527 This mountain is mentioned by Leo Africanus (Book 2, "Of the mountaine called Hanteta," trans. Pory, 2: 281): "Neuer did I see (to my remembrance) an higher mountaine, then that which the Africans call Hanteta. Westward it beginneth from Gedmeua, and stretcheth fiue and fortie miles Eastwarde, to the mountaine of Adimmei beforenamed." Robert Brown, editor of the Pory translation (2: 364–65, n. 85), identifies the mountain confidently as "the modern Jebil Mlitsin or Miltsin, of the Asif Sig," possibly

Angote, a region of Ethiopia; the same features would apply to all of these. But I know for certain that the air there is in motion, on the reasoning stated. But if it does not turn over ashes, that is possible, because the air is exceedingly rarefied, and exceedingly healthy too, for that reason. And this concurs with what is said about Mount Athos, if indeed any reliance can be placed in Solinus,[528] who has the same story. But if you think that is a fable, you have actually nothing against us. And so he wrote that Mount &201 Athos in Macedonia, which must be reckoned among the six highest mountains of the world (its rank among them is not fully agreed),[529] has the citadel Acroathos on its summit, and its inhabitants live one half longer than the rest of humanity, nor do ashes there get diluted with water nor disturbed by winds. Pomponius Mela supports this view about their longevity. And he says the same thing about the ashes.[530] Hence the air ought not to be motionless; but if it is, it must be moved gently and be pure and very rarefied. For the rotting of air when it is at rest is sufficiently established, like the grinding down of earth when it is shaken. This shaking follows three patterns: tilting,[531] earthquake,[532] and vibration. Vibration is free of risk, but earthquake never is, though occasionally it is free of disaster.[533] Tilting is associated with disaster—but I have seen tilting without it.[534] Certain marvels occur over and above these, yet arising from them—marvels that are erroneously thought to be of divine origin, like most others. Of this kind are the appearing of lakes, and more often of springs, and reversed flow of rivers upward, which goes on when their upper part is tilted in an earth movement, or is all shaken in its bed. Also

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the highest Atlas peak visible from Marrakesh, and locates it in his Map V, of "Marocco." He notes that in some of the earlier editions of Ramusio's version its name appears as "Hantera," but as "Anteta" at the heading of the article—and invariably as "Hantata" in the Latin edition. Cardano's source for the name "Solis" is unclear; Nenci points out that in Pliny (*Nat. Hist.* 5. 9) the word does appear, but as the name of a promontory, not a mountain, encountered by Scipio Aemilianus in the course of a campaign in Africa.

528 See n. 515 above. Of the inhabitants of Athos, the mountainous promontory near Thessalonike in Greece, Solinus wrote what Cardano attributes to him here; "ideo inde homines macrobios Graeci, nostri appellavere longaevos";—the Greeks called the folk there long-lived, using their Greek word, while we called them the same, using the Latin word (ed. Mommsen, 87).

529 It is in fact 1,935 m (6,350 feet) high.

530 Pomponius Mela, an author of whom little is known with certainty, may have flourished about A.D. 44. He (*De situ orbis*, 2. 2. 10) does indeed make these statements about Athos, its citadel, the longevity of its inhabitants ("dimidio longior, quam in aliis terris, aetas habitantium erat") and the persistence of the ashes from the altar on the summit.

531 "inclinatio."

532 "succussio"—shaking from below.

533 "ruina."

534 The following seven sentences first appear in 1554.

some lowing sounds or terrifying bellowings, and disorganised voices like the wailing of people falling in battle, and the spontaneous tinkling of little bells. These events are related among prodigies such as occurred in the year 1224, in which they all came about through an earth movement. But there was no prodigy—except this single one, that the earth trembled so vigorously that all these consequences ensued. For when the event has come about, the consequences will follow. &202 But perhaps it cannot come about without a prodigy, although it is accepted that these things occur from natural causes.It comes about when combustible material is burnt—sulphur, salt, nitre or saltpetre,[535] and bitumen. When these are actually ignited and find no exit, as in mines or artillery, they move and shake the earth, worst with saltpetre, middling with bitumen, slightly with sulphur.

To continue: the question arising here is: why saltpetre burns reluctantly and more sluggishly than sulphur, but causes a greater shock, and shakes artillery,[536] and makes a greater noise. The reason is, that saltpetre, being drier, also blazes faster when it has been purefied, and only burns more sluggishly if impure; when pure, being dry, it flares up in a moment. Sulphur in a fatty state[537] needs a delay to take fire. Another reason is that since it is earthy, it takes longer to be changed into flame. So there are two causes: it burns faster, and it is earthy and compact, and so takes up more room for that reason, and creates more impact than sulphur. Sulphur, as we will show later, is in fact fatty and airy, and minimally earthy. Saltpetre is actually compact and of very rarefied substance.[538] It is cleansed[539] in this fashion, as Vannoccio Biringuccio instructs. Three parts of ash of olive stones, one of quicklime, a medium and fourth part of liquid alum, one hundred and twenty parts of water. Let them boil and be cooked till there is a [401]reduction of nearly a half. Of the water later trickled through, two to four pounds are added to the saltpetre &203 while it is collected with boiling water, at the point at which the foam looks like leaping out of the pot with the vigorous surge.

There is another nobler way, but it is more costly. Put saltpetre in an iron vessel, let be held in the iron vessel and covered. Bring up charcoal and roast it till it melts. But if it has not melted completely, as is revealed with the cover off, put the cover on again and press on with the fires till complete melting takes place. When it has been sprinkled with a very fine sulphur dust, set fire to it if it has not taken fire of itself. Then let anything fatty burn away, for that will be on

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535 "halinitrum."

536 "machinas."

537 Sulphur "exhibits a remarkable and complex series of forms." One is γ–sulphur or plastic sulphur, made by pouring molten sulphur into water, and is pale yellow and rubbery (Sherwood Taylor, *Inorganic and Theoretical Chemistry*, 605). This seems like the "fatty state" of sulphur here.

538 This does sound self-contradictory.

539 "purgatur."

the surface. Then take it off the fire, and leaving the earthy sediment at the bottom, everything gathers together into the aspect of white marble. It is therefore obvious that anything fatty resists rapid combustion; bitumen contains a certain amount of salt, and so creates more shaking from below than pure sulphur does. All shaking from below possesses something more than simple impact,which is why objects struck by a vibrating[540] impact are more readily broken.

Serra ratio.

Besides, experience shows this, first of all: stick a sword into a peach, hold the sword up with your hand, and hit the sword with a stick—with a slight blow you will split not just the peach but also its stone. I have actually tested this quite often. Furthermore, people say that if you place the leg of an ox (the bone, that is) on a heap of chaff, and then put an axe on the bone, and strike the axe with a handful of the chaff, the very bone gets broken; and even if it is extraordinary that this is true, people still agree that there is very great power in a vibratory impact.[541] So the reason needs enquiry. It seems to me that one or both of the following explanations holds good.

First, that if the object &204 struck is lying on a solid plank, the plank's resistance makes the object and the actual part that receives the blow more compact; hence it yields minimally to the impact. For a compact thing is harder to split the more compact it is. But if it lies on a soft underlay, like a couch, or on chaff, or on simply nothing at all, it cannot be compacted, but gapes and splits open. This is why dry things get divided in this way more easily. Another reason is that with a vibratory impact, the thing struck bounces back,[542] the previous impact not yet being over.[543] This is why what is struck has to come apart altogether, if it needs to bounce back while the other blow is still in being.[544] Hence if a sword is long, the blow is struck again more powerfully and duplicated, so that it[545] will come apart[546] more easily. But if a sword cunningly shaped is wider, and is hit at its end, it will be struck again powerfully, because it takes up[547] a lot of air, and therefore will sever very hard things.

On a different basis, the barbarians make curved swords,[548] in which the hollow is on the back, and they put quicksilver in it; while this settles down near the hilt, it makes the weapon very light—as it moves downward, it augments the

540 "tremulo."
541 "tremulo ictu."
542 "redit quod percutitur."
543 "nondum finito priore ictu."
544 "redire debet altero ictu manente."
545 The target object, presumably.
546 "dividetur."
547 "excipit"; this may mean "displaces" here.
548 Scimitars.

impact so much in weight and speed as to cleave armour, if the edge is tough.[549] Nothing more savage can be devised for man's use than this sort of sword, provided the user possesses strength and the steel is hard and tough.[550]

From this the basis of a saw can be deduced. It is made, as everyone knows, with teeth set alternately. It cleaves things on this basis: everything that has a known structure[551] can be stretched and pulled. There are two parts in it: the gap and the occupied.[552] The occupied part can be bent. Two features appear worthy of enquiry: how the &205 gap adds impact; and the other feature, how the obliquity contributes a great deal to the speed of cleaving. We shall see from this how and in what way the teeth are made longer and more slender, and more separated[553]—and at times thicker, more closely packed and shorter, as in a file—for a file is a saw provided with short, close-packed and blunter teeth. In the same way, a saw is a file, refined with long, open and sharp teeth. And in both of these tools there is a range:[554] one saw is more open-toothed and sharper than another saw, and one file has teeth blunter, more close-set and shorter than another file. At the same time we should also consider whether these features follow upon each other—as for instance whether short and close-set and blunt teeth do so, or some features have a different formula.[555] To start with, then, there seem to be three advantages of this gap:[556] first, that a saw picks up impact by downward movement; for the air, as we explained, stimulates and assists movement;[557] indeed, there is falling through empty space, and the impact is increased. Secondly, that the iron gets cooled. For if iron is enclosed on all sides, it heats up, and while heating, it grows soft, and it bends and loses all its strength. Thirdly, because through this separation the teeth can be made oblique. If the saw remains entire, this obliquity cannot be introduced, or if it is introduced, it cannot be turned to use; and if it is, it cannot persist.[558] There are two advantages of the obliquity: the

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549 "firma."

550 The following two paragraphs (except the final sentence) first appear in 1554. The final sentence first appears in 1560.

551 "rationem."

552 "inanis et solida."

553 "rariores."

554 "discrimen."

555 "finem."

556 "Inanitas"—evidently the space between the teeth.

557 In a modern age where powered circular saws are very familiar, it is necessary to bear in mind that the hand saws that preceded them are plied to and fro on a slope, or even almost vertically if the saw is long and is used by two men, one of whom is in a pit. Cardano seems to be pointing out that between teeth the saw can pick up momentum, to use a more modern term.

558 I do not see the picture in Cardano's mind; a saw's teeth are of course "set" by being bent alternately to one side or the other, but if there were no separations between teeth, "setting" would be meaningless.

one, to provide an exit for the sawdust, the other, to allow a wider cleft between the teeth to be made more readily. For if there is a wider cleft because of the size of the teeth, the saw will still be operated with difficulty, the cleft clamping the teeth tightly. And there is &206 another advantage, that the saw does not heat up too much.

When then the item being taken apart is soft, we frequently use saws with well-spaced,[559] sharp-pointed,[560] and rather long and oblique teeth. When the wood is very hard, the saw will have teeth that are short and less pointed, and also closer together and less oblique. But if the intention is to cut iron, teeth will be needed that are thicker, so as not to break, and shorter, and straighter too. But we make them close-set, because such teeth do a small job, and slowly. And as I said, we call this kind of saw a file. These will be the rules even more in the case of steel. Weight is also more necessary in these cases. Lightness is preferable in a saw, since we look for speed in one. So what is preferable in soft things is spaced-out, long, pointed, oblique, and light. These then are the number and size of the advantages of being spaced-out and oblique in saws. But in a file, since as I said,[561] it is plied with slight effort, the teeth have been made for breadth and manifold. It has indeed been repeated quite often, that tools that complete their task quickly need more force, but those that need small force demand a longer time. "Muffled"[562] files of this sort are made, since they are very thin, and are lubricated with separation water. The water aids the cutting and reduces the noise.The best of these adopt the shape of tongs; it is hardly possible for a tool that is freely pulled across not to make a noise; but those that are held down like this do not jump up, and they cleave by scraping or cutting without making a noise.

But I return now to the signs of earthquake, since I recall that I have explained the causes and varieties.[563] When &207 well waters reek of sulphur or something else metallic, or they quake, or are muddied,[564] or warm up, or dry up without explanation, they predict that an earthquake is imminent. In this

559 "rarus."

560 "acutus."

561 But I don't think he has said this previously.

562 "surdae."

563 "species."

564 "turbantur."

way Anaximander[565] and Pherecydes,[566] (each in his own times) predicted an [402]imminent earthquake, and rationally: for the earth's breathings can affect waters quite readily at a distance, and so too more quickly than they can shake up the huge weight of the earth. But you need not suppose the whole earth gets shaken; it is recorded that Egypt never has been. For solid regions are not shaken by the earth's movement, because they do not take up air, nor are muddy ones, like Egypt, because they are devoid of cracks, nor are sandy ones, because they are permeable.[567]

But some of these do get shaken, because the depths of the earth differ from the surface. Mountains are sometimes created by earthquakes, and in fact have a triple origin: either the earth is shaken by frequent movements and swells, and produces mountains as when blisters are being brought forth from a body, like the mountain named Modernus in Campania near Lake Avernus;[568] or else when ground is heaped up by the winds, as often occurs in Africa; or else in association with running waters, which is a particular and very frequent event; or else the earth is washed away by the sea, leaving stones behind: a river's water runs down into a valley, and a mountain itself pushes up stones from the valley, and this is why all mountains look rocky. Their height consists only of what land is left, since fields are eaten away daily by the rains, and the earth itself cracks. But the stones mostly pile up,[569] besides not cracking, as we will &208 show later on. The valleys are really carved out by waters and torrents, and this is why they are lower than fields and level places.

Cliffs in the sea are established on the same principle,[570] and they arise from islands when the earth is eaten away by waves. With the addition of earth, or as it swells, they emerge as islands. For this reason, most islands have plenty

[565] G. S. Kirk, J. C. Raven, and M. Schofield (*The Presocratic Philosophers*, 2nd ed. [Cambridge: Cambridge University Press, 1993]) offer no support for this tale of Anaximander. But they present this quotation from *Anaximenes* (probably an associate of Anaximander, ca. 500 B.C.): "Anaximenes says that the earth, through being drenched and dried off, breaks asunder, and is shaken by the peaks that are thus broken off and fall in. Therefore earthquakes happen in periods both of drought and again of excessive rains; for in droughts, as has been said, it dries up and cracks, and being made over-moist by the waters it crumbles apart" (158). This may be the origin of Cardano's statement here.

[566] Pherecydes, probably in the sixth century B.C., was said to have predicted an earthquake, after drinking from a well. For sources and details, see H. S. Schibli, *Pherekydes of Syros* (Oxford: Clarendon Press, 1990), 5.

[567] "perspirent," which classically means either "breathe everywhere" or "blow constantly," so that the present translation is a guess.

[568] A deep lake in a one-time crater near Puteoli, thought in antiquity to lead to the Underworld (Vergil, *Aeneid* 6. 237 and other classical works). Puteoli (modern Pozzuoli) is 12 km north of Naples.

[569] "crescunt."

[570] "ratio."

of mountains, and if the sea dries up, crags emerge as mountains. Hence there is nothing remarkable about parts of ships turning up in mountains near the sea—and oysters and other molluscs.[571] Indeed, how is this different from those mountains having once been cliffs of the sea, or some serious flood having at some time preceded them? And though mountains often stand up to attacks by water, they do sometimes collapse, with water tunnelling into their roots—but this is uncommon, and happens only to small mountains. But they do tumble down through earthquake, and with the earth cracking their weight makes them descend into the depths. Others are gradually destroyed by the sea. And they get smashed by strong winds and by cold conditions, which make it perilous to be beside rocks and under them. Human assiduity also sometimes levels hills: it is related that Hannibal dispersed Alpine ridges with hot vinegar, and thus got the better of them.[572] This is a small matter if we take heed of the mountains—but a great one, if we take heed of the advantage. In a way,[573] caves are themselves the mountains' enemies. They are created by an earthquake developing in a dry spot during the earth's cracking, also with waters rushing down through the hidden fastnesses of the mountains; hence there are rivers in some of them. They are also created by fiery exhalation, which burns stones, then surpasses them and ejects them. Hence there are a number of caves that breathe out something deadly, such as the Plutonian orifice that is situated beside Hierapolis in &209
Phrygia, in a mountainous part of the land. Its orifice is located in a hill, two thirds of an acre[574] in size, and is surrounded by square enclosures, which are so veiled by mist from the earth that they can barely be seen. The actual orifice can

[571] Eckman (*Cardan*, 76) points out that Charles Lyell, celebrated geologist of the nineteenth century, gave credit to Cardano for this insight that the sea could once have reached high up on mountains.

[572] Livy's account (21. 37. 1-6) of Hannibal's use of hot vinegar to clear a path through the Alps in 218 B.C. runs as follows: "Since they had to cut through the rock, they felled some huge trees that grew near at hand, and lopping off their branches, made an enormous pile of logs. This they set on fire, as soon as the wind blew fresh enough to make it burn, and *pouring vinegar over the glowing rocks, caused them to crumble.* After thus heating the crag with fire, they opened a way in it with iron tools, and relieved the steepness of the slope with zigzags of an easy gradient, so that not only the baggage animals but even the elephants could be led down" (Livy, *History of Rome*, trans. B. O. Foster [London: Heinemann; New York, G. P. Putnam's Sons. 1929], vol. 5 [books 21–22], 109). See also J. F. Lazenby, *Hannibal's War* (Warminster: Aris and Phillips, 1978), 47. To illuminate the question whether the vinegar story is credible, in 1956 Sir Gavin de Beer "repeated the experiment myself by lighting a fire around a block of limestone and then pouring onto it cold water containing 10 per cent acetic acid." Steam and froth emerged and the block split, but further details are absent (*Hannibal's March* [London: Sidgwick and Jackson, 1967], 113).

[573] "quasi."

[574] I.e. one "iugerum."

admit a person, and if a bull is put into it and pulled out at once, it is found to be dead. When Strabo had put sparrows in, he pulled them out dead at once.[575] He was unharmed through an antidote used by the priests of the Magna Mater,[576] who alone knew it; and they do not breathe in the air while they are doing their examination. Some of the priests thought they could hold out, because they had been castrated.[577] There are, however, aids and precautions against this source of harm; if fans are employed, as we said previously, they will do us double good. First, because they will cleanse the air of vapours, by their very motion. Secondly, because they make torches keep burning and prevent their being put out; for those, no air is so harmful as to be beyond cleansing. The warning is, that it is better not to enter when the torches go out without a wind—that is the most convincing sign of a deadly environment. But nowhere are there more caves of this sort to be found than in Italy. There is one between Naples and Puteoli, where the road bends towards the marsh of Anagni. These caves damage the head especially, both because it is weaker than the heart, and because it has no partition to fend off evil vapours—air that enters the heart has to cross the lung's substance. And what also shows the sort of diseases is that those who are allowed in[578] start by trembling, then they lose the power of sensation and motion, afterwards they expire stupefied, &210 and those who have got away swell up—those who are dying swell up too.

Caves are not only lethal: some are health-giving, and if rightly used, one can sometimes find a therapeutic route to deal with regrettable diseases—for instance the sweat chamber of Salveata in the mountains of Baiae and Cumae,[579] in the mountain commonly called Tritulum. And there are some caves that can inspire a seer, as we recall used once to be written about the Delphic oracle from the viewpoint of philosophers. As a rule, on the whole the power of caves is hostile to the human race, and occupies the role of a poison. For if this exhalation could erode stones and the hardest rocks, what power will it possess against mortals themselves? However, an indication of safety is a flow of sweet and healthy

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575 He wrote a celebrated *Geographia* in 17 books, and lived from about 64 B.C. till after A.D. 21. It contains this tale (*Geographia*, 13. 4. 14).

576 Cybele, the mother-goddess of Anatolia in antiquity, known by the fourth century B.C.; her cult was brought from Asia Minor to Rome at the start of the second century B.C., and celebrated there and indeed in many regions of the Roman Empire with elaborate and occult ritual.

577 The following four sentences first appear in 1554.

578 "immittuntur."

579 Cumae is about ten miles northwest of Naples, and it and Baiae nearby were coastal resorts for the highest Roman aristocracy in the years of the early Roman Emperors. Cumae was the base of a celebrated Sibyl, a prophetess described by Vergil (*Aeneid* 6. 98, and see H. W. Parke, *Sibyls and Sibylline Prophecy* [London and New York: Routledge, 1989]), and Baiae acquired a reputation much later in medieval times for its medicinal springs.

waters through caves, and the flourishing of herbs and well-known trees on the cave's brink. But caves are also home to wild beasts and snakes. Everyone agrees that the most prominent is the Corycian cavern, the biggest and most convenient; indeed, laden mules reach it. It is in deepest shade, well-watered, exceptionally pleasing in showing perpetual greenness. Beside it is born the most famous crocus in the world. It is in Cilicia, beside the town of Corycus.[580] Caves are regarded as being very pleasant for their shade, breeze, springs, seclusion,[581] and verdure. The one here, being the most pleasant in comparison with the others, is accepted as the most attractive of the whole world.

Someone might perhaps wish to know what lies below harmless deep caves. The tale is told of King Philip,[582] that when metal resources[583] of great value ran out, he had ordered a diligent search. When people had made their way into a &211 mountain's entrance with food and lights, it was reported that rivers had been found there, and lakes of standing water which were not surrounded by earth, but by foggy shadowy air. And Joannes Leo the geographer holds almost the same view.[584]

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580 It appears that there was on the Cilician coast in Asia Minor a cave of this name, and the details Cardano supplies are to be found in Pomponius Mela, *De chorographia*, I. 72. Mela belonged to a place near the present-day Gibraltar, and wrote this work in three books in about A.D. 40, describing the world as he knew it. This cave was sufficiently renowned to be mentioned also by Pausanias (*Description of Greece*, 10. 12. 7) and others.

581 "recessus."

582 Philip II of Macedon (382–336 B.C.), whose policies were coloured by the need to secure valuable mines, and who took over the lucrative mines on Mount Pangaeon (west of Kavalla in Thrace, in northern Greece) in 357 B.C.; Seneca (*Nat. Quaest.* 5. 15. 1; Loeb 10: 101) wrote: "Many men were sent down by Philip into an old mine . . .to see what riches it might have . . .They descended with a large supply of torches . . . when they were exhausted by the long journey, they saw a sight that made them shudder: huge rivers and vast reservoirs of motionless water, equal to ours above ground . . . but with a vast free space overhead."

583 "metallica."

584 This sentence first appears in 1554. For Johannes Leo see n. 309 above. The account Cardano has in mind is perhaps (Book 2, "Of the town of Agmet," cited here by Nenci, 257 n. 206.) of a river near the town of Agmet, south of Marrakesh in Morocco, and runs (trans. Pory, 2: 272): "The water of this riuer looketh alwaies white; albeit if a man stedfastly behold the said riuer, it may seeme vnto him in colour to resemble the soile of Narnia, or the riuer Niger of Vmbria in Italie. And some there are which affirme, that the very same riuer runneth vnder ground to Maroco, and not to breake foorth of the earth, till it come to a certaine place very neere vnto the said citie. Many princes in time past, being desirous to know the hidden and intricate passages of the said riuer, sent certaine persons into the hollow caue, who the better to discerne the same, carried candles and torches with them. But hauing proceeded a little way vnder ground, there met

But why am I considering these deep hidden questions now?—a point will be provided where it will be appropriate to discuss them; now let us look into issues suitable for the whole enquiry. [403]The whole earth is stable, round, and in the middle of the universe; these facts are proved by mathematicians. Nor indeed can the whole air be moved from its position, any more than heaven can be at rest; nor do the mountains in any way spoil the roundedness of the earth. For even if authors fabricate many tales, no mountain occupies with its height the thousandth part of the earth's diameter.[585] Mathematicians have discovered the circumference[586] and diameter of the Earth along the following lines.[587] (1) Either at a lunar eclipse they have found out the separation of the hours in the same equinoctial equidistant circle.[588] Having obtained this, by a journey on the earth they have reached the separation of the places. By multiplying it by the twenty-four hours of one day, and by dividing it by the hours of separation of the lunar defect,[589] they have found out the circumference of that circle. Then by geometrical proof they have estimated the circumference of the equinoctial circle at its maximum, and by multiplying it by seven and dividing it by twenty-two, they have reached the earth's diameter by a sufficiently refined method.[590]

(2) Or else, by proceeding from the south to the north, they increased the altitude of the pole by one degree.[591] Measuring their track, they discovered 87.5 Italian miles.[592] For it is by these, not the paces[593] of Ptolemy, that we now measure the &212 distances of places. So extending 87.5 miles through the 360 degrees of heaven (it is divided into that number), we have 31,500. If we multiply this

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them such a flaw of winde, that blew out their lights, and perforce draue them backe to the great hazard of their liues, so that they said they neuer felt the like."

585 Since the Earth's diameter is about 12 750 km and the height of Everest is about 9 km above sea level, what Cardano says is true, but not overwhelmingly so!

586 "totius ambitus."

587 "sic."

588 On the availability of clocks in Cardano's time (spring or weight driven), see 178 (1560) in this Book, and Landes, *Revolution in Time*. It is also known that Jean Fernel, a near contemporary of Cardano, had an "horarium" which he trusted to supply the right time (L. Figard, *Un médecin philosophe au XVI^e siècle: étude sur la psychologie de Jean Fernel* [Geneva: Slatkine, 1970], 21–23). There is much more detail on clocks and time-keeping in O. Mayr, *Authority, Liberty and Automatic Machinery in Early Modern Europe* (Baltimore and London: Johns Hopkins University Press, 1986).

589 "defectus."

590 On this procedure, dating back to Aristarchus of Samos (about 310–230 B.C.), see A. van Helden, *Measuring the Universe* (Chicago: University of Chicago Press, 1985), 7 ff.

591 "pars." For details of a contemporary practical measurement made of a degree of latitude, see Forrester and Henry, *Jean Fernel's On the Hidden Causes of Things*, Introduction, 10.

592 "passuum 87 ac 500 invenere Italica." On length of the Italian mile, see n. in Book I at 34 (1560).

593 "passus."

circumference of the Earth by 7 and divide it by 22, the Earth's diameter will be 10,022[594] miles.[595] But it is folly to want to aim at an exact quantity in these issues. So let us remove the 22 and say that the Earth's diameter is 10,000 miles.[596]

But sailors are driven about by many errors, and as on their own they pursue a wavering and not straight course, misled too by the uncertain and changeable impact of the winds, they have described a much greater circumference of the Earth. But while this theory[597] is very true, it also corresponds to extremely reliable experience; it helped the Spaniards a great deal, who when they appreciated that such a prolonged and distant journey is incompatible with the size of the Earth, shrank it to one third of both distance and time, by assessing their error by careful reasoning.

And these are benefits of subtlety. But the Earth is not regarded as all of one kind; hence Aristotle was right to divide it into two: first the metals and minerals, that is, what is obtained by digging and is transmutable. What is obtained by digging stays the same, and is genuinely earth. It is transmutable in its kind only and in appearance;[598] it passes over into metals or juices or other items of the same kind; we will deal with this in its proper place. And there are two kinds of genuine earth. One is pure; it is of a drab colour, or one close to drab. The other is impure, and contains nothing metallic; it is of a different &213 colour. In fact, all earth which is endowed with a colour not its own has been altered by an exhalation, according to Aristotle's view.[599] But Theophrastus thinks it is a difference of heat.[600] Yet both views are correct: for at times under the latter sort of earth metallic features are found, and this one is tinted with an exhalation; at times there is almost nothing, and this one is tinted from heat alone. But the sort that is tinted with an exhalation glows, so to speak; the sort that is affected by heat alone does not glow, and has a dusky colour, either like iron, or dark. There are

594 "M. XM.XXII"; on the assessment of the diameter, see also Nenci, 259 n. 210.

595 "mille passuum."

596 For an account of the history of measurements of the earth and of the universe as a whole, see Van Helden, *Measuring the Universe.*

597 "ratio."

598 "visu."

599 Aristotle, *Meteorologica*, III. 6, 378a22–33 (Loeb 287): "The dry exhalation by the action of its heat produces all the 'fossiles' [items dug up], for example, all kinds of stones that are infusible—realgar, ochre, ruddle, sulphur and all other substances of this kind. Most 'fossiles' are coloured dust or stone formed of a similar composition, for instance cinnabar [for Cardano and later, mercuric sulphide, but see n. 213 above] . Metals are the product of the vaporous exhalation, and are all fusible or ductile, for example, iron, gold, copper. They are all produced by the enclosure of the vaporous exhalation, particularly within stones, whose dryness compresses it together and solidifies it . . ."

600 On the difficulty of linking this statement to a specific passage in the works of Theophrastus, see Nenci, 260–61 n. 213.

actually as many colours of earth as there are kinds of colour: sallow,[601] which is light-coloured;[602] yellowish, like a kind of potters' clay called yellow ochre[603] by the Latins; green like chrysocoll,[604] red like realgar,[605] blue like lapis lazuli,[606] dark like the clay called pnigitis,[607] which is metal-free. And although other earths are made known on the pattern of the metals, we do not mean these, since they are found to be metal-free, these ones that reproduce those colours to perfection. And there are yellow ones, as I said, and drab ones, and ones that are tinted, such as the one that when rubbed with Eretrian brass becomes violet. Strato of Lampsacus[608] used to think there was white earth, on the evidence[609] of ash. There are people who attribute to Aristotle the view that earth is of no colour at all. Here we follow the line corroborated by the evidence of our senses, and take no account of these trivialities. And so we spoke of "drab," because pure earth is usually like that, and what is like that is usually the best too. The best earth, then, is not invariably of this one colour, although, as I said, it is usually drab; some dark earth is excellent, as if it were the colour of potter's clay and unspoilt by any mishap. &214 Mishaps comprise the dry, the scaly, the corroded,

601 Cardano uses here the Greek word ὦχρος.

602 "candidus."

603 "Sil," to Pliny (*Nat. Hist.* 33. 158–59) . This is the Latin word for yellow ochre, "a mixture of hydrated ferric oxide with clay, sand, and other impurities." Caley and Richards (*Theophrastus on Stones*, 173–74) mention that it was a pigment often obtained from Attica in Greece, at least in classical times.

604 This word in its original Greek form means "gold solder" and in practice generally means "malachite," a green-blue salt of copper, or some closely similar salt of copper, and Castelli says that chrysocoll is green. But "chrysocoll of Agricola" apparently means borax, and in Book V at 386 (1560) Cardano writes that chrysocoll is borax. Borax is colourless. Both malachite and borax have been used for gold soldering. But Caley and Richards (*Theophrastus on Stones*, 105) will have none of this identification with borax, preferring green copper carbonate (malachite) as the identification for any period prior to the sixteenth to eighteenth centuries A.D. And they point out (106) that malachite, while a useful green pigment, can in fact be used as a solder for gold. Crosland (*Historical Studies in the Language of Chemistry*, 103) says the term was still ambiguous in the 16th century.

605 "sandaracha," arsenic disulphide. But Crosland (*Historical Studies in the Language of Chemistry*, 105) mentions that Vitruvius unfortunately used this word to describe red lead. .

606 Cardano uses the Greek word κύανος.

607 πνιγῖτις, "suffocating earth," is briefly mentioned in Pliny (*Nat. Hist.* 35. 194) as being like Eretrian earth.

608 Head of the Peripatetic School of philosophers after Theophrastus, about 280–260 B.C.; I cannot trace a source in his works for Cardano's statement, but Nenci (262–63 n. 215) has traced Cardano's source for it to Georgius Agricola.

609 "argumento."

the greying, the one resembling pumice,[610] the crazed.[611] There is a sterile earth, one in which grows foliage with long sharp exposed thorns, or broom or heath.[612] This feature surely indicates, if anything,[613] unsuitability alone. Nor is this the only such indication; another is when there is plenty of one kind of vegetation, a kind that you do not see in meadows, but only in wild and dry places. So earth that is very rarefied, like potters' clay, soft, excellent at taking up water,[614] good at imparting colours, free of defects, and giving off a very pleasant odour when dried and sprinkled by a shower—this is the best earth for trees and fruits.

But why does this earth smell good when wetted by a slight shower after long drying? The real reason is that during dry spells the mild humour held in the earth is concocted[615] by the moderate natural heat; then when a shower comes on, it gets mixed with water and it breathes forth. So it smells excellent, because it is also excellently concocted. Thus a pleasant odour indicates both a temperate heat and maximal fruitfulness. From the task itself[616] one may readily draw a conclusion: when the vegetation and trees flourish in it, particularly those that require a fatty soil, you have sure evidence of goodness of soil.

A triple classification is derived from the earth's substance: thick, and it is called sand; rarefied, and it is like potters' earth; and medium, the usual kind. Now look—even in actual earths you can see the distinction of subtlety. For sand being sterile, it is unfit for almost any earthenware. But potters' earth is fertile for plants, and well suited to earthenware manufacture. Indeed, of that earth the best is the one &215 that produces clover; the next is the one producing grass for pastures. The one that produces goatherd's rue is fruitful; the one that feeds a vine well is best for all trees, though the olive tree repels the vine. So since one earth suits fruits especially, another pastures, and another trees, you will recognise each kind from its own sign. But in places where lucerne[617] comes up, to assess pastures there is no surer sign than the amount of that plant. Further, that at times earth originates from the kind like potters' earth, the earth once called Tasconium,[618] out of which they used to make lookout posts[619] in

[610] "pumicosa."

[611] "fistulosa."

[612] "bruchum"—Castelli supplies "eruca" as a synonym for this word, unknown to *OLD* and *L&S*. Scaliger (*Exercitatio* 36 [147]) reproves Cardano for being ignorant that Dioscorides and Theophrastus called this plant "erica," while the Lombards call it "bruc," the Italians "brecole," the "Ruteni" "brughiera," and the Basques "Brana."

[613] "si quid aliud."

[614] The word "hygroscopic" would no doubt be anachronistic here.

[615] "concoquitur."

[616] The producing of a concoction.

[617] "medica."

[618] Pliny, *Nat. Hist.* 34. 69: there, "tasconium, a white earth resembling clay," is the material for crucibles used in gold refining.

[619] "speculas."

Spain, and nowadays, as the physician Georgius Agricola, a distinguished man, reports, a tower at the town of Corverium[620] in Saxony; it is less disturbed by fires, winds, and [404]showers than a structure built from cement and stones. Its weight makes it safe from winds, its hardness makes it safe from fires, and its impermeability[621] makes it safe from waters. So it should be fatty and very fine-grained and compact,[622] and consequently scarce too. Some earth becomes more rarefied in the cold, as that of Gosselaria[623] does; when it is in slabs, it gets very thin from the cold. Sand is of three kinds: river sand, sea sand, and sand that has been dug up.[624] Here, subtlety displays a considerable range:[625] the sand that has become the most fine-grained makes cements for the permanent[626] foundations of walls, so long as it is pure; through such small subtlety over many centuries life is added to structures, or passes away.[627] River sand is better, so long as it is not enhanced by technical skill, because it is salt-free, and is purer than sand that has been dug up. There are also ranges of earths according to their uses (such as ordinary earth, approved by &216 farmers; potters' earth for potters; reddish earth for timber craftsmen;[628] Cimolian earth[629] for fullers, blue earth for painters, Lemnian earth[630] for physicians, whiting[631] for silversmiths). All these earths depend and are created according to waters and heat. Hence there is nothing better than to possess well-watered earths, for they bring forth in profusion every kind of fruits, trees, and herbage.

But there is proper uncertainty on how the earths can stand out above the water level.[632] Some people have said that this is because it is God's will. By saying so, they blame Him more because they have failed to discover a cause through which He operates, rather than praising God because He could bring it about without a reason. Those who say that the dry land was made for the sake of

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620 "Cervecia," not "Corverium"; Agricola wrote of a "high furnace" there (trans. Bandy, 27).

621 "quòd non recipiat."

622 "praetenuem et densam."

623 This is probably Goslar, some 60 km southeast of Hannover in Germany. Also mentioned in Book V at 377 (1560).

624 "fossilis."

625 "non parvum discrimen est."

626 "aeterna."

627 "perit."

628 Perhaps to mark their wood.

629 This is "cimolite," hydrous silicate of alumina (*OLD*). Cimolus is an island in the Aegean sea. Pliny (*Nat. Hist.* 35. 196–98) discusses its use for the fulling of cloth, as well as a range of medical uses.

630 On Lemnian earth, see n. 474 above.

631 "argentaria"—*OLD* gives "creta argentaria" = whiting.

632 "aquis supereminere."

animals do explain a purpose[633] why it was made, but in order to assign a purpose other causes are required, which they hardly explain at all. Some people would say that the dry land is supported by the stars; firstly, this is a violent[634] state of affairs; then, the stars ought to have been fixed and unmoving, and what is more, they are from an opposite region, so that some would hold up Europe from the north, and others Brazil from the south, opposite Europe. If you suppose two centres, one for water, the other for earth, this other one will be different from the centre of the universe. And there will be two centres of gravity, and parts of the Earth will not be able to rear up from opposite regions — yet they do so, as Brazil and Europe do; and there will be no Antipodes. Those who want the Earth to be held up by air enclosed in caves set up a violent arrangement both ways, with Earth propped up on the top of air, and air held forcibly in caves. Furthermore, there would have to be huge caves, to &217 support Asia, Africa, Europe, Brazil, and so many islands — and if they think straight, the whole Earth will be one single cave, and it will be extraordinary that such a huge mass does not show the least gap, so that if it did, the whole globe would collapse, and with the air driven out, it will be extraordinary that such a mass of water does not pass down into it. Aristotle in the *Meteora* reckons that the water does not get in because of the pole, because the earth there is higher.[635] But in this way the earth would not be round, nor would there be earth under the equator,[636] nor would that height bear a relation to the difference of position between earth and water. Just suppose (it can hardly be true) that Earth is a thousand miles higher: if water's place is around the Earth, and it is higher than Earth on a basis of size by two thousand miles, the Earth under the north pole[637] will still be a thousand miles under the waters, and much more everywhere in other places.

I am ashamed to have said this, because of the man's[638] celebrated authority, more than I am ashamed of my criticism, in which everyone appreciates that I am constrained[639] by a love of truth. So it is not the case that the water is so extensive, nor is it a portion of the whole Earth worthy of notice. But because a little water lies on top of the Earth, because of its lightness, it occupies any

633 "finem."

634 In the Aristotelian sense.

635 This is not quite what Aristotle (*Meteorologica*, II. 1, 354a22–24; Loeb 129) said; he was discussing the flow of water in seas, and "as, therefore, rivers in particular are found to flow down from high places, so in general the flow is greatest from the higher parts of the earth which lie towards the north." Scaliger (*Exercitatio* 37 [147–53]) expands at length upon this point.

636 "aequinoctiali," with "circulo" understood.

637 "sub arctico ipso."

638 Aristotle's.

639 "tractum vi."

low-lying irregularity on the Earth's surface.[640] While it makes so many seas, the vast ocean, and so many rivers on this basis, still the Earth is reckoned quite large. But if you take account only of the perimeter,[641] the thing might perhaps be true that the Earth is larger, but when you take account of depth, there is no comparison. The evidence is that there is nowhere (deep pools[642] apart) where the sea's water has a depth worth mentioning, but elsewhere a mile, or half a mile, or two or three tenths of a mile[643]—a &218 depth which on comparison with the Earth's size is like the depth of the sweat on a human being. In deep pools the water is somewhat deeper, because it is appropriate for that location to be filled with water rather than with the very light air. So the earth is solid below, in the part where a small amount of water is instilled because of a hollow; elsewhere a little air is confined, not much, for a few years, not for good.

But if water were an element and as huge as that, the largest part of the sea ought to be bottomless.[644] For surely, if instead of a thousand paces, it were to occupy a thousand miles, or double that, it would be reasonable that no trace of a bottom would remain, if the sea had the size they think it has.[645] But when the bottom is evident everywhere except in deep pools, as I said, and all the deep pools are a limited item,[646] manifestly water is not such a plentiful element.

And so there are three elements, of which the lightest and largest is air, the next in size earth, both of these being necessary in themselves. Of these, air is on top, earth is down below, and water—minimal and as it were dispensable—in the middle between them. For if humanity could exist without food, as stones for example do, water would not be necessary. But water was created because it was necessary not just to be alive, but to be nourished, and generate and grow. The space for water being more roomy than the element water, there is in fact some low-lying portion in the Earth, which is why the Earth protrudes everywhere in the continent and islands, and provides a habitation for humanity and the rest of the animals.

&219 From this, then, the manner in which inundations readily occur is clear—people usually call them floods; since the water is of a moderate nature, and established on the Earth's surface, it overwhelms low-lying places if it

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[640] Scaliger (*Exercitatio* 38 [155]) perversely interprets this as meaning that every such depression is water-filled, which is manifestly absurd. He on the same passage (157) in a Figure appears to offer the ratio of ocean depth to radius of the Earth as 1:4,000.

[641] "ambitus."

[642] "gurgites."

[643] The sense is confusing here.

[644] "fundo carere."

[645] "Nam certum est, si pro 1000 passibus, 1000 passuum millia obtineret, aut duplum huius, quod par esset magnitudinem si tantam quantam existimant haberet, nullum fundi apud mortales vestigium superfuturum."

[646] "angusta quaedam res."

increases a little, and is also soon fetched back, because not much of it exists even after an increase. But if there were as much of it as is supposed, a great increase would be needed for inundations; there would therefore be none of them. And if they had happened just the same, they could hardly ever have been fetched back, unless after the virtual extinction of the human race; the Earth would have lain under water for a number of years, not months. Yet as Plato relates, these inundations happened not once but many times;[647] and they were over again in a few months. So water was made of small amount, to leave space for a habitation, and to direct its coldness to moderating animal life, not to destroying it. And as this generating of mingled things was only necessary on the Earth's surface—the effect being that it would occupy the surface only, in which metals, plants, animals, fish needed to be [405]nourished and generated—it was made of small amount, and on the Earth's surface. But because there was a considerable danger that it might be too much consumed by the air and by the Sun's rays, perpetual movement was linked to it, and that is why, as I said, waters that do not move quickly rot and are much broken up. One should also beware of its generation under the poles and in the mountains, and when the water is too much burnt up in hot regions, nature sees to it that the place is as low-lying as possible, and that is why all waters flow towards the Equator.[648] Although consequently the Nile rises from the Mountains of the &220 Moon near the Tropic of Capricorn,[649] still after traversing the equinoctial circle it passes through the torrid zone, and by that impetus is conveyed into our sea[650] near Alexandria.

So there the greatest part should consist of the cold wet element, where more of that was needed because of the Sun's heat. At the same time, care is taken of the safety of the intervening places, for with the water always flowing into the same part, the regions could not be submerged; people who free fields from flooding and who dry up marshes take care of this. If then there was no downhill flow of waters, the whole Earth would already be a swamp. And so making what lies towards the Equator more downward-sloping, and what is close to the poles a little higher, was the work of the Sun's consuming heat, and of the cold near the poles preserving very high mountains; we have explained already that heat consumes and eats away, while cold preserves. This is why the zone adjoining the poles is, has been, and will ever be very high, and the zone in between very low. Hence it was inappropriate for the Sun to circle round from all directions,

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[647] Plato, *Timaeus* 23b: "You [Solon] remember but one deluge, though many had occurred previously."

[648] "meridies"—i.e. they run south in the case of the northern hemisphere, of course.

[649] In fact the Blue Nile rises in Ethiopia about halfway between the Tropic of Cancer (not the Tropic of Capricorn, which is very far to the south, and Cardano transposes these names again later at 1240 (1560) in Book XXI) and the Equator, and the White Nile from Lake Victoria, more or less on the Equator.

[650] The Mediterranean.

or at the poles; for if it were to travel over all the globe during individual years, the Earth has to become even,[651] and consequently either be all dried up, or all overwhelmed by waters. But since this would not suffice to afford the rivers a free flow, with higher places quite often intervening on the way, producing inundations, and stagnant decayed waters, wise Nature has granted water the ability to ascend as much as it goes downward, so that in this way, getting the better of mountains and hills, it finally reaches the sea. Water is therefore in small amount, and located on the Earth's &221 surface. But if there were as much as is believed, and it lurked underground, it would either be in motion and stimulate perpetual movement of the Earth, or rot through being at rest. Since we see neither of these outcomes, water cannot possess a size worth mentioning in comparison to earth, and cannot lurk in the depths of the earth, but we have shown that our senses tell us that there would not be much of it on the surface either. So water is quite limited in amount; but the Earth, being the base for animals, and the centre of the Universe round which the stars revolve, and the foundation for everything, has acquired a size suitable enough, although in comparison to the circuit of heaven it occupies the role of a point.

There[652] are very many kinds of waters, but on the basis of location and size they are distinguished thus: water that is salty and accumulated together is called a sea; if it is sweet water, it is a lake; if it is entirely immobile, it is a swamp. Mud has to be generated in these. But if it is not deep, it is a bog. If it is flowing, it is a river or stream, so named from the flowing.[653] If it gushes forth, it is a spring. If it is assembled from rain or snow, it is a torrent. Therefore clearly torrents are not always in flow. It is a brook if it runs along in small amount. The deepest swamp of all is the Alcyonian one in the territory of Corinth, and though it is less than three stadia in circumference, Nero could not plumb its depth[654] by linking ropes many stadia long, the water was held in such deep pools.[655]

People say that there is a lake like this on an island of the royal Danish or Cimbric Chersonese called Bornholm,[656] and its bottom is not detectable[657] although the lake is &222 small. In general, on the Norwegian coast the caves, and hence the pools, are very deep. Since the water actually makes its way penetrating between lofty cliffs lying close together, and the more so if there are deep caverns in the channel, the lake absolutely has to be narrow, with a very deep eddy.

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[651] "aequalis."

[652] This paragraph first appears in 1554.

[653] I.e. "flumen" and "fluvius" are derived from "fluere," to flow.

[654] "plumbo explorare."

[655] Pausanias, *Description of Greece*, 2. 37. 5–6.

[656] An island in the Baltic, still of the same name. This paragraph first appears in 1560.

[657] Translating "percipitur" instead of "percipit."

The Maeotic swamp is salty, and famous for that and for its size.[658] But we have explained the causes and the manner of the downflow of rivers sufficiently accurately, in my view; however, there has often been doubt about their source, with their perpetual and manifold downflow of waters. So the Philosopher considers that they are generated.[659] Solomon[660] thinks they originate from the sea by a circuit, others that they are accumulated from rain and snow, others that they emerge from springs hidden under the earth.[661] It is clear that all the water is not generated in mountains, nor out of the air, since Tanais[662] gushes forth in the plains of Muscovy; but it must originate from there, since water does not run upward, unless it runs down from the higher mountains. It cannot ascend either from the sea to such a height as the mountains' top, and before it could reach the mountains, there is no basis for it not bursting forth everywhere.[663] The rivers would never be diminished, and the sea itself would not suffice for so many rivers, but would dry up from time to time, since most of the water would evaporate[664] under the Sun's heat. Also, this movement under the Earth would shake it, as I said, and there is no reason why water should flow from one mountain and not another. Again, it is hardly likely that water could be rendered so free of all saltness and bitterness. It cannot come only from snow, since water still flows from mountains not covered with snow, nor wetted by any &223 showers. Indeed, it is totally incredible that such a mass of waters, and one so permanent,[665] should be generated.[666]

So what is to be said? It [water] comes about from all these causes, but the greatest one is, that air passes over into water, and later on, snow and showers contribute a good deal persistently to this. Herodotus too thinks that this is the cause

[658] This is the Sea of Azov, a northward extension of the Black Sea. This sentence first appeared in 1554.

[659] "generari," i.e. presumably created *de novo*.

[660] In the Old Testament Book of Ecclesiastes (1: 8), attributed to Solomon, "All rivers run into the sea, and the sea does not overflow; the rivers return to the place from which they run forth, to run once more."

[661] Aristotle (*Meteorologica*, I. 13, 349b3–35; Loeb 91–3) mentions the view that the water drawn up by the sun falls as rain, and is stored in various sites to issue forth into rivers irregularly with the seasons; but he doubts whether sufficiently large sites could exist, and suspects that in addition water might form independently within and below the earth from air under the influence of cold.

[662] The river Don, in Russia.

[663] Cardano may have in mind a siphon, which enables water to run down into a valley and then some way up the other side; and if it bursts under the pressure at the valley's bottom, it will indeed "burst forth everywhere." Such siphons were familiar in Roman times, e.g. at Pergamum in Asia Minor.

[664] "evanescat."

[665] "perennem."

[666] Generated "*de novo*."

of the inundation that the Nile creates in Egypt.[667] Indeed, his view runs like this, that the Nile starts to swell at the summer solstice, and increases over the 45 days following, and floods Egypt, and over about the same number of days it declines again.[668] Of old (I mean in the time of Herodotus) a 14-cubit[669] increase used to bring the maximal fertility, but an increase of 8 cubits brought barrenness. Later, in Strabo's time,[670] it used to increase less, and did not produce a rise of eight cubits.[671] But during the present time, whether through the detection of some mistake[672] or through a change in practice, when it overflows to the extent of fifteen arm's lengths, the fertility is greatest. From fifteen to eighteen it [406]produces slight damage, with large risks. Above that, Egypt is under water, and suffers serious damage, with an obvious range of flooding, if some develops. From fifteen down to twelve, it leads to a lack of agricultural production, but a slight one; from twelve to ten, to a serious one. Below that it never seems to happen.[673, 674]

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[667] Herodotus (*Histories*, 2. 19–25) noted that the Nile regularly rose for a hundred days from the summer solstice. Some Greeks believed the reason was north-westerly winds at that time, blowing the Nile's water back from its delta; others, that it was fed from Ocean which runs round the whole world; Herodotus also noted the belief that snow melting at that time fed the flood, but considered this impossible since the Nile's sources lay in such hot regions, and himself he maintained a somewhat complex explanation involving the Sun's heat.

[668] Text present here only in the 1550 edition appears as Appendix 4 in Nenci, 316.

[669] A cubit corresponding to about 525 mm, this rise amounts to about 7.35 m (about 24 feet), and the lesser rise of 8 cubits amounts to about 4.2 m (about 14 feet).

[670] The statement about the cubits is in his *Geographia*, 17. 1. 3.

[671] The following eight sentences first appear in 1554.

[672] Evidently in the handling of the Nile.

[673] "subsistere."

[674] Cardano's source here is no doubt Leo Africanus (see n. 309 above), Book VIII, "Of the old citie called Mifrulhetich" (trans. Pory, 3: 879–80): "In the midst of Nilus, ouer against the old citie, standeth the isle called Michias, that is to say, The isle of measure, in which isle (according to the inundation of Nilus) they haue a kind of deuise inuented by the ancient Egyptians, whereby they most certainely foresee the plentie or scarcities of the yeere following thoughout all the land of Egypt. This island is well inhabited and containeth about 1500 families; vpon the extreme point or ende whereof standeth a most beautifull palace built in my remembrance by a Soldan, and a large temple also, which is verie pleasant in regard of the coole streames of Nilus. Vpon another side of the Island standeth an house alone by it selfe, in the midst whereof there is a fouresquare cestern or chanell of eighteene cubits deepe, whereinto the water of Nilus is conueied by a certaine sluce vnder the ground. And in the midst of the cestern there is erected a certain piller, which is marked and diuided into so many cubits as the cesterne itselfe containeth in depth. And vpon the seuenteenth of June when Nilus beginneth to overflow, the water thereof conueied by the said sluce into the chanell, increaseth daily, sometimes two, and sometimes three fingers, and sometimes halfe a cubite in height. Vnto this place there dayly resort certain officers appointed by the Senate, who viewing and obseruing

This is an entirely reliable recent account of this matter. But I come to Herodotus, whose account of the Nile's swelling, poorly translated and worse understood, I have recently corrected and explained. Strabo too supports it. No one should think it strange that, since the Nile has its source where the &224 Sun's presence makes winter for us in our summer, which for them is the start of winter, the generation of snows and showers provides an increase for the river, and therefore an opportunity for flooding. But now the inundation has grown much more prolonged, for in Strabo's time the fields used to be drying up already in sixty days. The reason for the inundation is the size of the river. The largest of rivers, as Arrian[675] wrote, is in fact the Ganges;[676] after it the Indus,[677] then the Nile.[678] Therefore the Ganges is first, the Indus second, the Nile third, the Danube fourth.[679] The fifth is in Libya, called the Niger by Ptolemy,[680] and is no less than the Nile; it rises from the mountain Thala;[681] this river is now called Senega[682] by the Lusitanians.[683] No river whatever runs into the Nile. The Acesines,[684] which

the increase of Nilus, declare vnto certaine children how much it hath increased, which children wearing yellow skarffes vpon their heads, doe publish the saide increase of Nilus in euerie street of the citie and the suburbs, and receiue gifts euerie day of the merchants, artificers, and women so long as Nilus increaseth. The foresaid deuise or experiment of the increase of Nilus is this that followeth. If the water reacheth only to the fifteeneth cubit of the foresaide piller, they hope for a fruitfull yeere following; but if it stayeth betweene the tenth and twelfth cubits, then it is a signe that corne will bee solde tenne ducates the bushell. But if it ariseth to the eighteenth cubite, there is a like to follow great scarcitie in regarde of too much moisture: and if the eighteenth cubite be surmounted, all Egypt is in danger to be swallowed up by the inundation of Nilus. The officers therefore declare unto the children the height of the riuer, and the children publish the same in all streetes of the citie, charging the people to feare God, and telling them how high Nilus is to be increased. And the people being astonied at the woonderfull increase of Nilus, wholy exercise themselves in praiers, and giuing of almes. And thus Nilus continueth fortie daies increasing and fortie daies decreasing; all which time corne is sold very deere . . ."

675 Arrian, *Anabasis*, 5. 4, 6 (Loeb 2: 11, 23).

676 2,700 km long in fact.

677 3, 180 km.

678 6,484 km.

679 2,850 km.

680 The Niger is 4,030 km long.

681 Its source is in fact in Guinea, north of Sierra Leone near the western edge of Africa. This sentence first appears in 1554.

682 The present-day Senegal river is perhaps 1,000 miles long, i.e. 1,600 km.

683 Inhabitants of a region corresponding roughly to modern Portugal.

684 Pliny (*Nat. Hist.* 6. 71) mentions that this river (now the Chenab) is a tributary of the Indus, and the same work describes it as well endowed with bamboos (16. 162), figs, (12. 23), and gems (37. 200). A river of the same name is mentioned in Thucydides (4. 25. 8), but runs into the Aegean.

(runs into the Indus, is about four miles broad, on the authority of Arrian.[685] But where the Ganges is narrowest, it is twelve and a half miles broad, and no limits can be seen. If the tales are true, the Spaniards in Brazil have found other rivers of unbelievable width, such as the Plata, which were debouching into the sea at a mouth thirty miles wide. There is also the Maragnonus,[686] which when entering the sea is 80 miles wide. The Dabais and the St Martha are 30 miles wide, and as people say, these three are on the north coast beside Paria.[687] But over time, the basis of size alters. There is a kind of reciprocation[688] of all mortal things; rivers flowing in have commonly dried up not only other channels into which they flow, but even seas. Herodotus recounts that the Achelous[689] &225 running out into the sea carried into it so much sand (this is how they dry up seas) that it attached the Echinades islands at their middle to the mainland. Polybius is the authority for this: that the river Don and other rivers in his time filled up the sea and the Maeotian swamp[690] so much that it had no more than seven forearm lengths'[691] depth of water, and became sweet instead of salty.[692] Strabo[693] relates that some of the Echinades islands were already linked to the mainland, and are being linked during the coming days, since the most distant one is only 15 stades from the mouth of the river Achelous.

But now that we are engaged in an account of rivers, it will be to the point to wonder why the Nile alone is free of breeze, or at least used to be—Herodotus persistently states this.[694] It should be of great concern to us to investigate the causes of things, in case things that are over in some cases should appear in others as time goes by, and we should later on be stuck in doubt. A breeze, then, turns up especially when water has taken up mild heat[695] from the Sun. The evidence is that it arises around rivers in summer at dawn and sunset, not at midday; when

[685] Roman author, and governor of Cappadocia about 135 A.D. He reports the breadth as fifteen stades (*Anabasis of Alexander*, 5. 20. 8; Loeb 2: 65.)

[686] Maragnon was an early version of the name "Amazon" river.

[687] Paria, a peninsula in Venezuela, is where Christopher Columbus first landed on the American continent, and far away from the mouth of the Amazon in Brazil. The text is defective here (see Nenci, 280 n. 248) and hard to reconstruct with confidence.

[688] "vicissitudo."

[689] The longest of Greek rivers. Herodotus (*Histories*, 2. 10.3) does mention that the river had attached half the Echinades islands to the mainland, but does not mention the sand.

[690] See n. 658 above.

[691] "ulnas."

[692] Polybius, *Histories*, 4. 40. 7–9.

[693] *Geographia*, 10. 2. 19.

[694] Herodotus, *Histories*, 2. 27: "I mentioned the fact that no breeze blows from the Nile; I would suggest, in explanation of this, that the usual thing is for winds to originate in a cold region, not in a hot one."

[695] "teporem."

the Sun is rising,[696] and not drawing things upward, the air is propelled by the motion of the water. The air, chilled by the water, creates a pleasant breeze, which we commonly experience around rivers in summer around dawn and sunset.[697] But since the Nile's source is surely within the Tropic of Capricorn[698] and travels entirely through the hot region, it will never be able to pick up a breeze — if some is created, it is at once destroyed by the Sun's excessive heat. A river is purged of &226 all earthly filth over the same path over which it cools the air, and is therefore salt-free; however, there could be some where salty matter runs into it from nearby. But even if this could occur, an instance of it would not be easy to find, for the reason stated. Thus the Nile, coming from very distant regions, and being scorched by the Sun's heat, carries very healthy water along with it.

But all the seas are salty, and bitter as well; when I have first set out the reason for this, I will add the question before us. We often see in our neighbourhood how water from a shower can swell rivers, while after rainstorms the rivers that were diminished before get so swollen that they flood the fields. Also, some streams, of which no more than a ditch full of stones was left, run during a number of days with such a generous supply of water picked up either from the Sun's showers or from melted snow, that they take on the role and the appearance of a great river. A stream differs from a river only in not continuing all year; and its cause is not like that.[699] So if you visit mountains in the morning, you will find them moist.[700] Little by little, then, streams flow out, the water having been gathered inside and outside, and many of them unite to make a river; but unless it is helped along by rains or melted snow, it will always look slender. At that time a small amount of water is enough, not just because its channel holds only a little, but because when it runs sluggishly the same water is enough at a number of places. It remains beyond doubt that this is the reason why during the morning rivers generally increase, particularly at the point nearest to their wellspring; to be sure, at night a lot of dew comes down in summer, and a lot of cloud in winter; the result is that at the following &227 dawn the river starts to rise greatly, and especially in the middle of autumn and spring, when the hoar-

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696 "elevat" — but this verb is transitive in *OLD*, though Cardano uses it as intransitive here.

697 It may well be that here Cardano has some recollection of the passages from Pseudo-Aristotle (*Problemata* 25. 4, 938a23–32; Loeb 2: 57 and 939a16–24; Loeb 2: 63) cited here by Nenci, but he is not quoting them with any precision.

698 See n. 649 above on this Tropic; the word here is "circulus brumalis"; see *OLD*.

699 "nec illius causa talis est" — obscure.

700 Reading the "hudos" of both 1554 and 1560 and Nenci to be an abbreviation for "humidos," although there is no trace in the microfilms or facsimiles of any tilde or other mark in relation to the word, nor does any abbreviation like "hūdos" appear in McKerrow's list (see Bibliography). I am indebted to Professor Iain Donaldson for this suggestion.

frost coming down is melted by the Sun's mild heat. And so water, created within the mountain by the coldness of the rocks and outside it by night's help, flows gradually inside. A part is also gathered outside into streams, and thence a number of streams usually make up a little river, and a large one from a number of little ones — like the Po, the Danube, the Indus, the Euphrates. And this is the cause of the permanence[701] of rivers, as well as of their rise: rain and snow. But the Don, and all the springs that gush out from level places, are not created there, but in the mountains, and from there are conveyed to that spot to emerge there from the ground, on the basis we mentioned just above, that water under pressure from higher places runs upward as far as it had run down. The sea, however, only puts out salty springs; some originate very close, but are salty. Although its tides make this very difficult, [407]I would not deny that with its waters running down below the ground with a great far-reaching impact, a spring of sweet water could start to gush out.[702] The evidence is that saltiness falls off with the length of the interval, because when wells are dug, the further they are from the sea, the less salty they are. But perhaps this may happen less through salt being separated out with distance than through addition of other waters, sweet waters. However, it is to be reckoned that the well water which the Milanese call "Hausus"[703] originates from the sea.[704] In fact the actual water gets sweet, not so much through impact[705] as through the length of the interval between it and the sea, and not so much through the admixture of other waters, sweet waters, as through the heaviness of salt. For when the salt in water has come to rest, it descends to the bottom through its heaviness;[706] but in &228 running water it is repurified by earth. This is why the sea is neither at rest nor in flow, but is stirred up by the tide so as to remain salty. There are three ways, then, in which water welling up from the sea's springs turns out sweet some distance away: by admixture of sweet water; by flow and hence by purification through mud and sand; and by the heaviness of salt making its way down of itself. And also, the sea itself provides this benefit of sweet water. But what Aristotle felt about the origin of rivers seems to be correct:

701 "perpetuitas."

702 Aristotle (*Meteorologica*, 2. 2, 354b17–19; Loeb 133) raised this possibility: "So some say that rivers not only flow into it [the sea] but out of it, and that the salt water becomes drinkable by being filtered."

703 This is a curious word; not in *OLD* nor Forcellini's *Lexicon Totius Latinitatis* nor DuCange, but if it were "haus*t*us" it would mean "a quantity of water drawn up," and "hausus" as a variant of the deponent past participle of "haurio" is cited from Solinus, on whom see n. 515 above.

704 The next five sentences first appear in 1554.

705 "impetus."

706 "gravitas."

where they have flowed into a hollow wide space, they make lakes.[707] Now we have given the cause of rivers, springs, streams and lakes.

What remains is for us to explain the reason why the sea is salt. On Aristotle's view, which few have understood, it is the incessant fall of showers into the sea, already continuing from eternity.[708] Although the sea is not eternal in the place where it now extends, yet since a sea comes into being from another sea, it must be, and have been, eternal through the continuity of its waters. The evidence is that they all derive from one: the Mediterranean, the Red, the Black,[709] the Caspian, the Magalian,[710] the Hyperborean,[711] the German, the Herculean, the Cantabrian,[712] the British, the Sarmatican,[713] the Indian, the African, the Baltic, the Glacial; then gulfs, like the Barbary, the Atlantic, the Great, the Arabian, the Persian, and the Maeotian swamp,[714] are parts or buds of the Ocean. I am aware that Ptolemy took a different view of the origin of the Caspian Sea, and separated it from the Ocean—but it was not so in the view of Pliny, Strabo, Solinus,[715] or Priscian.[716] But this matters little, and it is not inconsistent, &229

[707] The Aristotelian origin of this statement is not obvious—perhaps *Meteorologica* 2. 2, 356a26–28: "The great rivers are those which flow for great distances through valleys, but they are joined by many tributaries . . ."

[708] Aristotle, *Meteorologica* (2. 3, 358a13–28; Loeb 153–55): "So some have maintained that the sea is made of burnt earth. Thus expressed, their opinion is absurd; but it is true that something of the sort makes it salt. For we must suppose that something happens in the world as a whole analogous to what happens in the phenomena just described: just as in combustion there is a residue of earth of this kind, so there is in all natural growth and generation, and all exhalation on dry land is such a residue. And it is dry land that provides the great bulk of the exhalation. Now since, as we have said, the moist and vaporous exhalation is mixed with the dry, when it condenses into clouds and rain it must necessarily include a certain amount of this property [i.e. the dry exhalation which being a residue is salty] which will subsequently be carried down in rain. The process follows a regular order, so far as things in this world admit of regularity. This then accounts for the presence of salt in sea water."

[709] "Euxinum."

[710] Not traced.

[711] A legendary race of Hyperboreans lived in the far North.

[712] Off Spain.

[713] It is not clear where such a sea could be in Cardano's time, though during geological time long before, a sea existed now so named.

[714] Sea of Azov.

[715] See n. 515 above. He (ed. Mommsen, 120) wrote that there is one Ocean, described by a chain of epithets according to shores, and these epithets comprise Arabian and Persian and German etc., including Caspian.

[716] He was a grammarian functioning in Constantinople during the first 20 years of the 5th century A.D., and adapted a work of Dionysius Periegetes, who probably wrote in Hadrian's time (*OCD*). The adaptation converted a work of 1186 Greek hexameters into one of 1087 Latin hexameters, suitable for schoolboys to study as an account of

whether there is one or not, that there is a sea not continuous with the others—such as the Dead Sea and the Sea of Galilee, which are continuous with each other, yet not limbs of the Ocean. But both are salty, and what is more remarkable, the Dead Sea is bitter as well, and hence has given reason for an investigation, yet it is further away from the Syrian Sea (part of the Mediterranean) than the Sea of Galilee is.

So it is clear enough that there is no sea separated from the Ocean but this one, and the Dead Sea, which was once called the Lake of Asphalt; and there is nothing to stop these too communicating with it by subterranean caves, and hence nothing to stop speaking of every sea being permanent, with a continuity[717] possessed by the waters but not by their position—and always salty. Three conditions seem in fact enough to preserve the saltiness: the Sun's heat, by which the Earth is scorched, and the waters decay because the sea does not stream along as rivers do; and it receives showers of rain. Indeed, all rain-bearing water is partly salty, because it is scorched by the Sun, and lapse of time leads to decay. But lakes are genuinely created, since rivers had them to start from. Hence, even if they receive rains, they still cannot take on a salty taste. Nor can there be salty lakes, unless the earth where they are brings forth salt; so they are not large either. The evidence can be the Acronian lake, which they now call the Constantiensian;[718] though anyone might think it a sea in view of its size, it is full of sweet water, not salty, because its source was from the river Rhine. The sea's huge size contributes to its saltiness, a size in which numerous mountains of salt must &230 be held, as if they were in a wide space of land. So with the salt being dissolved, and the daily tide contributing particularly, it comes about that the whole sea gets salty.

Hence out of one problem another arises, no less weighty: why is it that the sea undergoes the tide, not just once daily, nor every day, nor equally?—the Ocean visibly flows in and out virtually twice per day, and so do some few parts of the Mediterranean, such as the Adriatic gulf where Venice has been established. But the sea adjoining Ethiopia, which is called the sea of Gineghae,[719] is reported by Alvise Cadamosto[720] to flow over four hours and ebb over eight, while others flow and ebb over six and six. The main reason why seas flow and ebb is that

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geography. It mentions the Caspian at a number of places: e.g. lines 21, 696, referring to the interval ("ἰσθμός") between the Caspian and the Black Sea—i.e. they certainly ended up separate, whatever may appear here. See Bibliography under Priscian.

717 "status."

718 Lake Constance, also known as the Bodensee; Strabo (*Geographia*, 7. 1. 5) said that this lake was one end of the Hercynian (i.e. Black) Forest, but did not name it.

719 Identified by Nenci (286 n. 261) as a variant form of "Guinea," although Guinea does not adjoin Ethiopia.

720 In Latin, Aloisius Cademustus [*sic*] (1432–1488), Venetian sailor in the service of Henry of Portugal, the Navigator. For further detail consult *Grande Dizionario Enciclopedico*, vol. 3 (1967).

though they are salty, this[721] could not suffice for the preservation of the waters and the air. For if the sea's water does not move, it rots in containers,[722] as Aristotle testifies.[723] But the water in the Mediterranean, being shut in by winds, is more in turmoil, and therefore does not rot. We have explained in our *Astronomica*[724] how it is moved by the stars and Moon. All the seas are thus moved from the East towards the West, and behave as a unit,[725] as does the Ocean, since it is virtually[726] one element, and that one is moved by the stars.

So all seas that lie in direct contact with the Ocean are themselves moved by that motion, but those that are to the side are not moved that way at all, like the Mediterranean and the Red Sea, which are moved from the northern side; with the environment laid out like this, the impact of waters running from east and west must be broken up. And even if the Mediterranean appears to be positioned from the east, &231 as the Ocean lies to the west it enters the Mediterranean only on the backflow, since now it is not thrust onward by the stars, but just by gravity, and so cannot maintain its movement. Another indication of this is that within the Mediterranean itself, on the African coast close to Zygris[727] (a shore stretching out straight from east to west), the tide occurs through the layout of the shore giving limited help to the Moon's power. But the Nortican[728] sea, which lies close to the Equator, is carried very fast from the northern side adjoining Paria,[729] from the east towards the west, since there the Sun works upon the waters more vigorously. But in southern Surenum, from the Beragua region a very powerful tide exists; but where Norticum lies on the northern side, almost none. So the large size of the tide at full moon and new moon, and its smallness midway between,[730] and their risings and fallings with the moon towards the midpoint of heaven, [408]show that the waters are moved in the tide by the Moon; and their swelling follows the star directly and the time of revolution,[731]

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721 Apparently "this" means "not doing so."

722 "in vasis."

723 Not exactly: he said (*Meteorologica*, 4. 1, 379b4–6; Loeb 297): "Therefore sea water in small quantities decays rapidly, but in bulk it does not: and the same is true of other kinds of water."

724 Cardano's *Astronomica Iudicia* was written (or at least begun) in 1533; for details see Maclean, *De libris propriis*, M17, 53–55.

725 "totius habent rationem."

726 "quasi."

727 Not identified in the work of Leo Africanus on the N. African shore.

728 Not identified in the work of Leo Africanus on the N. African shore.

729 See n. 687 above.

730 "in quadratis."

731 I am unable to suggest how to modify the text, which is the same in 1560 and Nenci, and reads "tumorque illarum e sideris directo et revolutionis tempus," and have simply guessed the meaning. Nenci (289 n. 266) cites Pliny, *Nat. Hist.* 2. 212–15, which is very much about tides, without obvious clarification of the meaning here.

which is about twenty-five hours, the interval in which the Moon returns to the east from the east. And since the star,[732] following the earth in this way, appears to pass round the sea daily, why do ships hardly traverse six miles in an hour unless pushed by winds?[733] The reason is that it is not the whole of the water nor a part of it that follows the Moon, but adjacent waters are transferred into those adjacent to them—as if someone presses the flesh and raises up a swelling, and the flesh moves very little from its position, but the swelling will proceed rapidly along the whole leg. &232 But at Norticum, where we said there was practically no tide, but a flow three months long, like a river, ships have to move fast, since the same part of the water is always moving along.

But now that we are involved in these discussions, I shall speak out about the Philosopher's reasoning, on which he proves from the saltiness of the sea that the universe is eternal[734]; it is this: if the sea had a beginning, it was from the beginning either sweet or salt. It was not salt, since such an amount of salt could not be mixed in, because it would corrupt the water, for everything must be reckoned to be created pure. For what is coming to birth, like lakes and rivers, is free of taste.[735] This however is directed against Plato alone, who considered that the universe was generated by separation, as the *Timaeus* has it. And so Ovid said:

> God (and a better Nature) settled this dispute; he cut away the earths from heaven, and the waves from the earths, and the mobile[736] heaven from the dense ether. After he released these and extracted them from a random heap, he bound what had been put apart in harmonious peace.[737]

So it was appropriate that no sea has existed with earth and water introduced into it, since a salty thing comes into being only through mixing. But if it was tasteless from the start, and as time went by it became salty, salinity has epochs[738]—but it does not, and it is not actually saltier now than it was long ago—so the sea

[732] "astrum."

[733] Possibly the line of thought may be that there would be a current flowing in the sea.

[734] This is not a conclusion drawn by Aristotle in *Meteorologica* (2. 3; 356b7–8; Loeb 143) in which he addresses at length the problem of the saltness, and remarks that "it is then generally agreed that the sea had a beginning if the universe as a whole had; for the two are supposed to have come into being at the same time," but does not use the saltness of the sea to prove the eternity of the universe.

[735] Material from here including the quotation and the sentence following it first appears in 1554.

[736] "liquidum."

[737] Ovid, *Metamorphoses*, 1. 22–23.

[738] "aetates." Presumably it gets saltier as time passes. Scaliger (*Exercitatio* 53 [205]) doesn't discern the word's meaning here; "Non enim Latini sic loquuntur, vt hoc velint indicare, quod tu vis. Omnia enim quaecunque sub tempore sunt, aetates habent: etiam Caelum ipsum."

was never created, nor was the universe. Moreover, there are collections of waters even under the earth, with the appearance of lakes. Hence the Don in Muscovy, the Lycus in Asia,[739] the Tigris in Mesopotamia burst out with &233 continuous downflow. People say also that the Timaus in the district of Aquiliensis,[740] and a wellspring of uncertain name in Atinas,[741] originate like this. Since there are caves underground—not deep underground, as there are in the district of Gabii[742] at the first milestone from Rome, so that when chariots and horsemen went by, the ground used to shake—it is nothing to wonder at that the earth gets filled up with waters or gapes open of itself, or that the air gets contaminated from fissures.

And though this depth is small in comparison with the size of the earth, it still can overwhelm towns, let in lakes, and leave mountains with an uneven chasm, since what is at right angles[743] does not split. But the waters of wells, since some are springs, are generally hidden four feet down or a little more; if the water were continuous, the earth would split, and wells would all have the same depth. Their water is no hotter in winter than in summer, but does seem so, because the air in winter is chilly, and hot in summer; in comparison with it, the same water appears the other way round—hotter in winter than in summer; everything in the environment at the time is assessed by comparison with our body. And so the result is that while we are hot, what we touch will be judged as cold, and while we are cold, as hot. Hence in a bath urine seems colder to those who are peeing it out. Water warms up a little by drawing heat into the inside, because it[744] is unable to get out or spread out on the earth's surface. This is why snowfalls which are not too prolonged always normally bring fertility, and even prolonged ones sometimes do. In addition, all the earth in a district to which water can penetrate is bituminous, &234 or salty, or indeed metallic; hence it comes about that confined vapours heat up water. And this is why it happens (though not often) that some wellsprings are hotter in winter than in summer, by a sort of miracle. This makes the waters odorous, or heavy-smelling, and not without some taste; tastes are there to be recognised when the waters gush out, and to indicate whether to

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739 *OLD* gives for "Lycus" the name of numerous rivers in Asia Minor, especially "a tributary of the Maeander."

740 More usually the "Timauus," the modern Timavo, running into the Gulf of Trieste; Aquileia was a town at the head of the Adriatic near Venice (*OLD*).

741 There was a town of this name in Latium, and another in Lucania, both in Italy.

742 An ancient city of Latium, near Rome; "In some places the earth trembles when trodden on—for instance in the Gabii district not far from the city of Rome about 200 acres shake when horsemen gallop over them, and similarly in the Reate district" (Plin. *Nat. Hist.* 2. 209; Loeb 1: 339).

743 "è directo," which might perhaps mean this, and compare rock to timber.

744 Either the heat or the water.

avoid or use them. But if they are hidden, or exist in a dry place, their qualities can be recognised by this technique: take a lead vessel, or a new earthenware jar, if lead is in short supply, previously smeared with oil inside, with dry white wool with a pebble in its middle attached to its bottom with wax, dig it four paces below the earth at sunset, with the vessel's mouth turned downwards; take care that the wool does not fall out, and gradually cover up the earth dug out. The following day, dig up the vessel and examine the wool. If it is not far away,[745] with the cold of the pebble and the night, then with the wetness of the oil smeared onto it, it will turn the earth's vapours it has picked up into drops of water. Wring it out, then, and collect the water. If there is little, conclude that the water is still a long way away; if there is much, not far. You will readily determine its characteristics by its smell and taste. There are in fact some of these waters, even standing out on the surface at the time, which not only smell of salt or bitumen, but are even boiling hot, as at Aponus near Padua,[746] and they are so widespread that almost no province lacks them, since in a number of provinces, springs even burst forth in many places. France is rich in them, Germany much more so, and far more Italy, the mother of all good things. The reason for this must be fire, or decay, or natural &235 heat, or celestial heat. Celestial heat, especially in winter and by night, cannot suffice to make waters boil. Natural heat is not in actual existence[747] except in animals, since they have a soul and senses. Heat from decay cannot be enough, and it is improbable that matter should be generated and decay at the same time. The prolonged existence of this miracle shows the need for actual generation of matter. So what remains is that the reason lies rather in fire; unless its heat has reached the top, it has a light movement, which is why it goes out of itself. But there are two forms of fire: the glow[748] and the flame. For a flame to be there is incompatible with good reason,[749] because it needs an obvious means of ventilation,[750] and consumes a great deal of matter, so that whole mountains of bitumen used to burn even for a whole month. An earthquake [409]often used to follow, because of the vapour,[751] but water would still be much hotter, and sometimes become visible, and burst out from time to time in those places, though never seen before. The evidence that a flame underground cannot be permanent is that its bursting forth never happened except at intervals.[752] And

[745] "non procul absit"—water, evidently.

[746] Mentioned for instance by Suetonius (*Tiberius*, 14) who writes that the Emperor Tiberius sought an answer to an enquiry by throwing golden dice into this fountain, and "they may be seen today under the water."

[747] "actu non est."

[748] The glow of charcoal.

[749] "ratio."

[750] "respiratio."

[751] "exhalatio."

[752] The remainder of this paragraph first appears in 1554.

as can be seen, this occurs because of winds; when winds rage near places from which a flame often bursts forth, then one is to be expected the next day or the one after.[753] This comes about through internal heat, as occurs in lime confined inside by external cold—then the flame is increased by ignited sulphur or bitumen, as it is by bellows. This is what we promised previously to explain when we were discussing the craters of Etna. Gaining ground, then, it[754] &236 bursts out, on the basis which was explained in relation to mines. So if all this is compared together, we will be sure to conclude that a glow[755] underlies it.

But what is the source of its fuel, its movement, its ventilation?[756]—it was shown above that fire requires these three things. A dry porous stone provides ventilation, cherishing the fire exactly as hot ash does. Extra matter igniting continuously provides movement, and thus the fire changes its base and is in motion. For in this way our experience is that a snake is preserved in the soot so long as the fire survives. And it does not catch fire, because the bitumen is impure, and mixed with earth. So in all cases the matter that burns below ground is very like soot, which makes it certain that soot is a type of bitumen. There are then two reasons why it does not burst into flame: one is that the bitumen is impure, the remaining one is that it has no ventilation.[757] Thus it comes about that then the more rarefied part of it sometimes ignites and gives out a flame, and then an earthquake and a sound are heard. But because it is mixed with rock and cannot be well ventilated, it does not burst forth without a supply of matter, but is moved of itself.

But how is a confined fire not put out, or at any rate does not change its base while it consumes matter? There are two reasons for it not being put out: bitumen, and the coldness of water. The heat is collected inside by this, and ignites a fire just as in lime. That coldness keeps the fire in the same place, because it is always under water. But in a roomy space, water boils; in a confined one, it bursts forth. There are in fact four reasons why a small fire is enough for such a large heat.[758] &237 The first is, that it is not ventilated, as in hot rooms.[759] The second is the nature of the stone, which is tufa[760] and hot in itself, taking in a lot of heat, stable heat, and giving it back adequately. The third is the plentiful hot ash which is left, and is drier in its own nature; hence when water is poured on, this

[753] Strictly speaking, "perendie" means "the day after to-morrow."

[754] What "it" is is conjectural, since its gender has now become masculine, so it cannot be lime nor flame.

[755] "pruna."

[756] "respiratio."

[757] "non respirat."

[758] "fervor."

[759] The word here is "aestuaria," and occurs with this meaning in Jean Fernel. See Forrester and Henry, *Jean Fernel's On the Hidden Causes of Things*, 652.

[760] "tophus."

ash of ours which is much weaker heats up the water. Finally, the fourth reason is added, that this water is split up among trickles, and therefore easily picks up and retains heat— if it were gathered together, it would hardly warm up from a blaze of the whole mountain, and after being heated would also revert very fast to its own nature. This is why there is no sea, lake, or river that can boil, because of the plentiful supply of water. Springs, being smaller, do boil quite vigorously by themselves in this way.

But why is the majority of the bitumen not ignited? Because the only bitumen that can ignite is what is deprived of watery moistness. And as all the bitumen abounds in this moistness, and in this very point differs from sulphur, it must be dried before it can take light, and must offer prolonged resistance to the fire beside it. Thus it comes about that fire very gradually consumes the matter supplied to it. Then since for the reasons stated a fire cannot grow a great deal, nor be totally put out, and since much matter is ready for it, and a little heat is enough to maintain the burning,[761] the burning must continue for many ages. So it is clear that all the waters that are boiling are light by nature, and possess a therapeutic power.[762]

But quite different is water suitable for use to preserve health; the ideal water is free of colour, smell and taste, and perfectly clear, &238 and when drunk does not linger in the stomach—it is like that of the river Eulaeus,[763] which flows out through Susiana[764] from the Zagros mountain;[765] the Persian kings used to carry it along with them on expeditions—they took such pains to guard their life. In fact, for preserving life water comes next to air, as we explained in our Commentaries on Avicenna's *De Temperamentis.*[766] And it should be no wonder that Artaxerxes Longimanus[767] lived so long, since the Persian kings took such care in the choice of water and air. But in Aelian[768] I find "Choaspes"[769] instead of

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[761] "fervor."

[762] "medica facultate."

[763] A river now known as Rud-e Karun, in southwestern Iran, which joins the Shatt al-Arab at Khorramshahr (*Encyclopedia Britannica*).

[764] The district of Susa, between Babylonia and Persia, also known as Elymais, the "Elam" of the Bible (see Genesis 10: 22 and 14: 1, 1 Chronicles 8: 24 and 26: 3, and further references in the books of Nehemiah, Ezra, Jeremiah, and Daniel).

[765] This is a mountain range in the southwestern part of modern Iran.

[766] Cardano published commentary on Avicenna at various times in his career, and full details are to be found in Maclean, *De libris propriis.*

[767] This king of Persia reigned from 464 B.C. for forty years (*OCD*; but other dates are offered elsewhere).

[768] Claudius Aelianus (ca. A.D. 170–235) wrote collections of excerpts and anecdotes (*Variae historiae libri XIIII*). "Xerxes even brought water from the Choaspes with him" (*Variae* 12. 40; Loeb 385). The next five sentences first appear in 1554.

[769] Now the Karkheh, rising in the Zagros mountains and ending in a swamp bordering the River Tigris. See Strabo, *Geographia*, 15. 3. 4–6 on the Choaspes.

"Eulaeus." And I found that there is a river of exceedingly pleasant taste between the Ganges and the Indus, and the region's neighbours who are unable to drink from it drink the water brought to them by runners.

But the Choaspes is thought to be in the region of Media; however, Strabo differs, but if it were in India, it could hardly be moved across to Persepolis.[770] So the water of the Choaspes is excellent, and that of the Eulaeus is pleasant too, and was in use by the Persian kings.[771] It is beyond doubt that India possesses excellent and very pleasant waters. The closest to these in goodness are those of the Nile, but barely any of the remaining major rivers is esteemed. We have dealt with them in detail elsewhere. Others are famous for their chilliness—one used to flow out of Corinthian territory from a mountain top, and was colder than snow. Georgius Agricola[772] mentions one, the "mad water," inside the first milestone from Culma,[773] and said it was extremely cold, though seeming to be boiling. Furthermore, in Bohemia there is one called Furiosa beside the river Egram,[774] and when it boils in pots, it is notable not for cold but rather for emitting thunder. It makes a din as it falls, &239 assailing the ears. In a similar fashion, after the Rhine has left Lake Constance beside Scaphusia,[775] it rushes down cliffs so high that it is audible many miles away, and the crashing seems almost like thunder. The reason for the waters' noise is their fall from a height, or their emerging with vigour[776] from narrows; just as causes of coldness are snows, marble blocks, metals, heaven freezing stiff, and a rapid movement,[777] also a fall from a height, and the greatest one, a mixture of saltpetre[778]—this will be demonstrated later. But in some springs, this coldness is not perpetual; for instance, in Spain, in a district of the town Pesquera[779] de Duero, beside the great river Douro,[780] there is a wellspring eleven degrees distant from the Fortunate

[770] The site of ancient Persepolis, which was built between 520 and 450 B.C. and burnt to the ground by Alexander the Great in 330 B.C., lies some 150 miles from the Persian Gulf, in Iran, and some 300 miles from the ancient Choaspes river.

[771] Herodotus (1. 188) says that the king of Persia always insisted that his drinking water should be drawn from this river.

[772] Agricola (1494–1555) was a notable authority on mining, and the author especially of *De Re Metallica* (1556) and of other works; Nenci, 300 n. 287, supplies the reference here.

[773] Town in West Prussia, in Germany (*Orbis Latinus*).

[774] Now the river Eger, west of Prague, in the Czech Republic.

[775] Schaffhausen or Scafusia, adjoining the Rheinfall where the Rhine behaves as described here.

[776] "impetus."

[777] The remainder of this sentence with the nine subsequent ones first appear in 1554.

[778] The thought is obscure here, but see n. 783 below.

[779] The town on the Douro river in central Spain still has this name.

[780] "Durium," running out of Spain into Portugal and then into the Atlantic Ocean.

Isles,[781] fourteen degrees from the Equator,[782] which produces [410]water from the beginning of springtime, and a great deal in summer; at the start of autumn it begins to dry up, and stays dry through the winter. Blasius of Villa Franca, the Spanish physician,[783] thinks that the reason is (he wrote this as his own discovery) the depth of the channel, which prevents it drying up in summer, but in winter it is used up by the hot bowels of the earth.

Yet we have shown that in winter the interior of the earth is not hotter in a simple sense than in summer, but hotter in relation to the air. So since it is very cold, it has a share of saltpetre. But in summer it runs down in streams originating from the mountains, when the snows start melting. In autumn it dries up, since the waters from the mountains have stopped running under the earth, and that is why it stays dry in winter—and the snows are prevented from melting by the frosty weather. So this seems to be a regular feature,[784] that in spring and summer rivers swell more &240 than in autumn, but much less in winter. This wellspring is twenty miles distant from the once celebrated city of Valladolid.[785] People say too that in Elboganum[786] the water makes a considerable noise, and has an acid taste. Aristotle recalled that in the Sicanian district of Sicily there was once water which the inhabitants used instead of vinegar.[787] What is marvellous about that? — I have heard that near Rome, at Cardinal Triultius's villa, a water is found of bitter taste, and very healthy with it, so that it is regularly conveyed quite far to be mixed with wine and add attraction. It is accepted that it gets bitter from concocted alum and well-tempered moistness, for of itself it is astringent. However, when alum is mixed with wine, it is thought to arouse dysenteries. Thus they report that in Cardia, near the lake Dascyli, in a place called

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781 The Canaries. See n. 520 above.

782 This is a curious reckoning. Valladolid (see n. 785 below) lies at about 41° 40′ N, 5° 26′ W, and the Canaries at about 28° N, 17° W. Hence the two differ by a little over eleven degrees of longitude, but Valladolid is far from being 14 degrees from the Equator—it is 14 degrees of latitude *further than the Canaries* from the Equator, which is presumably what Cardano meant.

783 This Spanish physician flourished in Rome about 1550, and is celebrated for the observation that freezing could be accelerated by adding saltpetre to the ice mixture surrounding the material to be chilled.

784 "quasi generale."

785 "Vagliadolit Pintia"; Valladolid is now a major city in Spain, some 200 km NW of Madrid..

786 Richard Hakluyt (*The Principal Navigations etc.*, 4: 36–37) copies this more or less verbatim from Cardano, who has in turn derived it from Agricola (for reference see Nenci, 300 n. 287). This place is mentioned again in the present Book II at 243 (1560). It was in Bohemia (see 396 (1560) in book V).

787 Aristotle, *Meteorologica*, 2. 3, 359b14–17; Loeb 163: "Sometimes it [the water] becomes acid, as in Sicania in Sicily: for there it becomes both salt and acid and they use it as vinegar on some of their dishes." The following four sentences first appear in 1554.

White Plain, there is a water sweeter than milk, and another near the bridge which leads to Valdeburgum. And there are waters that resemble wine, like one once in the island of Naxos (one of the Cyclades in the Aegean Sea); hence Propertius writes in the third book of his *Elegies*:

> And in your honour, the odorous rivers through the middle of Naxos, rivers from which the Naxian crowd quaff your wine.[788]

It is hardly remarkable, when Pliny and Dioscorides[789] report that with age hydromel converts to wine. Aristotle attributes the cause of the taste of waters to their heat; earth thoroughly heated changes water and gives it a taste.[790] In this way too, some springs seem imbued with oil, like one in Saxony beside the notable town of Bruno,[791] and in Swabia[792] beside the convent[793] with the name of Lake Degerse, and again in a valley of the &241 Jura mountain. The reason is very fat bitumen—there is no doubt that bitumen contains oil. And so when water is washed out with oil floating on it, it presents itself as a spring of oil. But it is incredible that the whole should consist of oil. So it is not remarkable that a spring of oil should have gushed out near Alexander's tent, as Arrian[794] (most truthful of all Greek historians) relates—or one at Rome in the time of Augustus. But it[795] was not born; I do not assert that it was, and it makes no difference,

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[788] Propertius 3. 17. 27–28; nowadays in its second line, "potant," not Cardano's "potat," is read, and the Phillimore *OCT* edition makes no mention of Cardano's reading; Agricola too (see Nenci, 303 n. 292 in Book II) read "potant." The Butler & Barber edition of Propertius mentions (305) that Stephanus of Byzantium under the word "Naxos" reports a legend that a spring of pure wine existed on Naxos. In this Propertius quotation, "merum" (i.e. *neat* wine), is no doubt significant in the context.

[789] Dioscorides Pedanius lived in the first century A.D. under Claudius and Nero, and compiled a *Materia Medica* in Greek which treated drugs derived from the vegetable, animal, and mineral kingdoms in systematic fashion. Pietro d'Abano made a new translation into Latin, printed in 1478. It became the standard work for later centuries throughout East and West.

[790] In his *De Sensu et Sensibilibus* (440b30–441a29), Aristotle regards water as characteristically flavourless, and argues that any flavour it acquires cannot be due to "the power resident in heat," but heat is a co-operating cause.

[791] Now Braunschweig.

[792] "Suevia"; an area now consisting of Baden-Württemburg and parts of Bavaria and Switzerland.

[793] "coenobium."

[794] Arrian, *Anabasis*, 4. 15. 7: "While he [Alexander] was encamped on the river Oxus, not far from his own tent a spring of water, and another of oil nearby, came up from the ground." Alexander the Great (356–323 B.C.) became a major figure in the subsequent Christian tradition, as indeed he did in the Islamic tradition. See R. Stoneman, *Alexander the Great: A Life in Legend* (New Haven: Yale University Press, 2008).

[795] The spring, evidently.

since we have shown it is possible, and how it is, for it is rare for such things to occur, and they do so in few places, so that when they do, they are taken as prodigies.[796] Other people attribute such things to God. In Elis, a district of the Peloponnese, when the ashes of the Olympic sacrifices turned into pitch-like material[797] through the water of the river Alpheus,[798] the episode was made a superstition, because it used to occur because of the fattiness of the water. There are also acid[799] waters, such as those of Golnicium,[800] so to speak the opposite of the fatty ones. The same basis applies to colours: there is white water at the second milestone from Clauca, a town of Misena;[801] red water, as at Radera of Masena, in the river beside Radeburg,[802] and of old in Judaea near Joppa;[803] green water in the Carpathian Mountains near Neusola;[804] blue water, as at Blava between Feltrium and Tarvisium,[805] and people say something of this kind happened at Thermopylae too; very black water in the Aller, a river of Saxony, where it discharges into the Visurgis.[806] The causes are the colours of potter's clay, but of a thinner clay, since thick clay does not adhere to water, and hence does not colour it. Also, some waters change their colour, as does the Nile when it dries up in droughts; Theophrastus is the authority.[807] Some waters stay unspoilt, such as the Tiber.[808]

There is a similar range of difference in its smells. &242 Most water smells are unpleasant, because, as has been said, it is rare for earth to smell pleasant.

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[796] On the nature of prodigies, see Jean Céard, *La nature et les prodiges: l'insolite au XVI^e siècle* (Geneva: Libraire Droz, 1977).

[797] "malta"; *OLD* offers "a mixture of pitch and lime with fat or wax; also a kind of natural bitumen," citing Pliny and others, and the word appears to have no relation at all to the modern word "malt," which derives from Middle English and not from Latin origins. This sentence first appears in 1554.

[798] A river flowing past Olympia in the Western Peloponnese of Greece into the Ionian Sea

[799] "acres."

[800] Gelnica in Slovakia, 17 miles NW of Kosice.

[801] Meissen.

[802] Just east of Dresden, and very close to the Elbe river.

[803] This is not recorded in the Bible.

[804] Now Banska Bystrica, in central Slovakia.

[805] Tarvisium is now Treviso, some 30 miles N of Venice; Feltre is some 40 miles NW of there.

[806] The Weser; the Aller river discharges into it near Verden, some 18 miles SE of Bremen.

[807] Reference not traced.

[808] The text of material present only in the 1550 edition here appears as Appendix 5 in Nenci (316). The material of seven sentences following here first appears in 1554.

The worst stench used to come from the Aniger river in Elis,[809] capable even of harming not only the fishes but also human beings. And in a well near Methone in Messenia[810] water that smelled excellent used to be drawn up—the smell was reminiscent of a Cyzicene plaster.[811] Furthermore, a Cyzicene plaster used to consist pleasantly of crocus, myrrh, incense, and items redolent of iris root. It is clear, then, that the causes of contrary things are contrary, and that what smells good is healthy, and what stinks is bad. And other waters have in other places the power to generate plants, and this has been observed on a regular basis: the Meander river supports tamarisks, the Asopus in Boeotia reeds with deep roots, the Nile the Persian tree.[812] It will be legitimate to assess the powers of waters by these too.[813]

Some waters are light, others heavy. On Aristotle's authority, all the surface water is lighter, not just in rivers, but in springs and wells, and the heaviest waters are at the bottom; this is on the same scale of parts[814] as applies to the whole, because all the heavy ones move down, while the light ones float up.[815] Strabo[816] records that the water of the Eulaeus[817] was lighter than the others by

[809] The stench of this river in Elis (part of the Peloponnese) is mentioned by Strabo (*Geographia*, 8. 3. 19; Loeb 4: 61).

[810] Not the "Messana" of Cardano's Latin, which is the modern Messina, but Messenia, the south-western part of the Peloponnese, where Methone still is, south of Pylos.

[811] Cyzicus lay on the Sea of Marmara between the Aegean and the Black Sea. There is some faulty recollection of Herodotus here. He (*Histories*, 4. 75. 1) reports thus on *Scythian* women: "Their women make a mixture of cypress, cedar, and frankincense wood, which they pound into a paste upon a rough piece of stone, adding a little water to it. With this substance, which is of a thick consistency, they plaster their faces all over, and indeed their whole bodies. A sweet odour is thereby imparted to them, and when they take off the plaster on the day following, their skin is clean and glossy." He then goes on just after to mention a visit by one Anacharsis to Cyzicus.

[812] This is probably the Greek περσέα, Latinized as "persea," a tree with edible fruit mentioned at Plin. *Nat. Hist.* 13. 60 and 15. 45 (*OLD*).

[813] I.e. by the plants they support.

[814] "ratio partium."

[815] Pseudo-Aristotle (*De plantis*, 2. 2, 824a16–37) maintains that fresh water is lighter than sea water, and also points out that an egg sinks in the former and floats in the latter. But there is no distinction there between "water at the top" and "water at the bottom."

[816] In his *Geographia* (15. 3. 23) he wrote that an Attic cotyle ("nearly half a pint"—Loeb translation) of it weighed a drachm less than other waters. See also Plin. *Nat. Hist.* 21. 185; this latter ref. (Loeb 6: 291) runs: "The Attic drachma, for it is generally the Attic standard that physicians adopt, has the weight of a silver denarius, and the same makes six oboli, the obolus being ten chalci. The cyathus as a measure weighs ten drachmae; when the measure of an acetabulum is spoken of, it means the quarter of a hemina, that is, fifteen drachmae. The mna, that our countrymen call the mina, weights one hundred Attic drachmae."

[817] See n. 763 above.

a drachma (that is, by the measure of a small cup).[818] This, according to Pliny, is a fifteenth part. But let us pass on from these issues to water miracles: there are waters of enormous powers, so that they can regularly turn timber into stone. Albertus Magnus[819] records that in the Danish Sea near Lübeck, a tree branch was found in his time with a nest and chicks, and when branch, tree, and nest were turned &243 to stone, they still kept their purple colour. And Georgius Agricola records that in the district of Elboganum[820] near the town named from the Falcons, whole fir trees with their bark had been turned to stone—and what is more, that in their fissures the stone "pyritis" was present. And Domitius Brusonius records[821] that in the river Sylaris, which laps against the roots of the mountain situated in the district of the town named of old Ursentinora, but now Contursium, the leaves and branches of trees changed into stone—he stated this not on the authority of others, but on his own, being an inhabitant of the district. The barks on the stones show the years, by the number.[822] Similarly, the scattered drops of the Gottic spring (this is the name given to it by ordinary people) turn to stone. And in Dacia the [411]water of Cepusium[823] turns to stone when poured into vessels.

But the principle[824] is not the same in all these cases; those that change into stones through extrinsic heat can safely be drunk, since round all hot waters porous stones are generated; but springs that freeze solid are full of gypsum,[825] and not free of poison—cold hardens everything and assembles it in stones. This is why a good stock of stones is almost always present in the beds of rivers (except sluggish ones), on account of the perpetual movement which carries the earth away.[826] On the other hand, Aristotle testifies that in the sea they are formed in this way: foam is created by the clash of the waves, and is compacted later by other waves; and finally, dried by the saltiness and with the addition of finer sand, it solidifies into stone.[827] Although this was &244 said only of stones being created in the sea, it will be interpreted as applying to all that originate in waters. But in rivers, torrents, and springs, it is the cold that solidifies, instead of saltiness. Yet

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818 "acetabulum."

819 Albertus Magnus; on him see n. in Book I at 2 (1560).

820 See n. 786 above. The source here is Agricola, *De re metallica*, 7, trans. Bandy, 166.

821 Nenci has traced the information that now follows to Lucius Domitius Brusonius, *Facetiarum Exemplorumque Libri VII*, cap. 9; the work was published in Rome in 1518 and later at Lyons in 1562.

822 Of their rings, presumably.

823 Now Kirchdrauf (German form of its name) in Slovakia.

824 "ratio."

825 Plaster of Paris.

826 The remainder of this paragraph together with the subsequent one first appear in 1554.

827 Pseudo-Aristotle, *De plantis*, 2. 2, 823b11–18.

this cold is a kind of heat—some heats generate by dissolving, some by solidifying, and both by concocting. The heat that does it by solidifying is called cold because, on Galen's authority, nothing in a cold human being is solidified.[828] This heat is less than human heat, and so we call it "cold." So they have it in common to be generated from more rarefied earth and from foam. More stones are therefore generated in torrents and in running rivers, the sand being finer, the cold greater, and the foam more plentiful. And it is evident that foam consists of the fattier part of water, and in this way stones have life, for it is in this way that plants too arise. We owe this to Aristotle, therefore, who left us the seeds of so many good things. There are other water miracles: water used to spring from a very high crag adjoining Cyllene,[829] which used to perforate all vessels, and only horse hooves can convey it along. It used to be called "Stygian,"[830] I think because it used to despatch people to the next world.[831] It is said that Alexander the Great suffered from drinking it. After this water has run downward in streams, it mingles with the river Crathis. Josephus the Jew too reports that there was in Judaea near Syria, between the towns of Arcas and Raphanas which were subject to King Agrippa, a river called Sabbaticum, which used to flow daily except on the Sabbath—that was why it was so named.[832] &245 Coarse credulous folk ascribe something to religion which is due to a natural cause—enough water was assembled to suffice for six days, but not for a seventh. Indeed, the same cause applies in human periodic fevers—the universe is a large human being.[833]

Movement and transparency are features common to waters and the air, to the ether and to heaven. Special to the ether are lightness, purity, rarefied nature, very speedy motion, and being devoid of qualities—yet no more so than heaven. But since there are many types[834] of waters, they can hardly have a common feature. There are in fact waters of the sea, of a lake, of rivers, of swamps, of marshes, of torrents, of springs, of wells, cloud water, storm water, snow water,

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[828] Meaning obscure; might be translated, "nothing in a human being is solidified by cold [frigido]."

[829] Mountain in Arcadia, in the central Peloponnese in Greece.

[830] That is, water of the Styx; this river was in fact a real river in Arcadia in the Peloponnese of Greece, which plunges deeply down a black rock, later joining the river Crathis. It became regarded more as a mythical river in the Underworld, across which the entering souls were rowed by the ferryman Charon (see Brumble, *Myths*, 297–98). Pausanias (*Graeciae Descriptio*, 8. 18. 4–6, cited by Nenci, 311) refers to its water's inability to leak out of a horse's hoof.

[831] "manes."

[832] Reference traced by Nenci (311 n. 314) to Josephus (*De bello Iudaico*, 7. 5. 1), who reported this as a miracle. Josephus (born A.D. 37/8) was a Jewish priest who was nevertheless pro-Roman and became a pensioned Roman citizen. He wrote a history of the Jewish War; for further details see *OCD*.

[833] "Mundus autem homo magnus"!

[834] "species."

ice water, hot water, water gathered in a reservoir, and water in pools, to use that term.[835] The best is spring water; ice water weakens the stomach and limbs, as do snow water and storm water; it actually comes down from a lofty and cold place. It is less harmful than snow water, just as snow water is less harmful than ice water. Sea water is suitable for medicine. Water from torrents and fast-flowing rivers, and lake water give rise to a kind of dropsy called ascites, but lake water less so. The waters of gentle rivers, such as the Nile, Eridanus, and Tiber, are very similar to those of springs. Swamp water is bad, marsh water worse, worst of all pond water—besides dropsy, it gives rise to hernia of the gullet;[836] it creates a bad body condition and jaundice,[837] and fevers, and it shortens life. Hot waters do not all have the same power; they are discussed in medical treatises, just as are waters gathered in cisterns. Cloudy[838] waters contain salty, as I said, and semi-putrid stuff. In every variety of water, the &246 lightest are safer, and decay more slowly, being less moist and more concocted by celestial heat. This is why the drier they are, and the less they chill things (being closer to the substance of air), the lighter they are, and they decay with more difficulty, which makes them also much more healthy.

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[835] "aquae lacunales, ut ita dicam."

[836] "gulae herniam gignit."

[837] "morbus regius."

[838] "nimbosae"—this word in *OLD* and *L&S* means "associated with clouds and rain" and not "cloudy" in the modern sense applied to liquids.

[411] &246 Book III
On Heaven

Enough has been said about the elements. The subject now is heaven: whether it is eternal, as Aristotle believes,[1] or generated, as Plato does,[2] or created, as theologians do, it appears to have a diverse substance. Now first of all, what Alberic Vespucci[3] carefully recorded about the size of the stars during his third voyage to the Indies — that there are three Canopi[4] that are large, but not bright: the first nine and a half degrees away from the South Pole; the second, twelve away; the third, with thirty-two away, and it is the largest, but rather dark.[5] The

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[1] This is the thesis of Aristotle, *De caelo*, 1. 10–12, 279b4–283b22 (Loeb, 95–129).

[2] In the *Timaeus*, Timaeus says that "we must first investigate concerning it [heaven] that primary question which has to be investigated at the outset in every case, — namely, whether it has existed always, having no beginning of generation, or whether it has come into existence, having begun from some beginning" (2.73). And later (6. 27) he speaks of "the birth of Heaven."

[3] Amerigo Vespucci (1451–1512), sometimes known as Alberic, may have been the first to reach mainland North America on his first voyage (1497–8) and did reach Central America on his second (1499–1500); so America was named after him.

[4] Canopus, in addition to being a town and island in the Nile near the Mediterranean, is a single star in the constellation Argo. Vespucci (*Letters*, trans. Markham, 49) however reported that "I saw in the heaven three *Canopi*, two certainly bright, and the other obscure." He went on to specify their pattern, as he supposed it to be.

The Alexandrian philosopher Eratosthenes estimated the circumference of the Earth to be 250,000 stadia (see van Helden, *Measuring the Universe*, 5). Other estimates of the size of the Earth followed. Some writers reported that the Greek Posidonius (ca. 140–50 B.C.) used the greatest height of the bright star Canopus above the horizon, as seen from Egypt and from the island of Rhodes further north. He obtained a similar value, a bit smaller.

[5] "primum scilicet, partibus novem cum dimidio ab australi polo; secundum, duodecim; tertium, qui triginta-duabus partibus ab eodem polo distat, maximum, sed subnigrum." It may be wondered how early astronomers could assess the size of stars, when they and most of the planets are effectively points. But from the early Greek astronomer

Conciliator[6] records, though in reliance on the account of others, that there are some large stars there which are not very bright, such as we have mentioned above. Ptolemy too refers to Canopus as a very bright star, but does not describe its size. However, I think this is the last of those [412]described by Vespucci[7]—he is a very well-known man, and at the &247 tiller[8] of a ship. But those two stars closer to the South Pole, once unknown, resemble clouds, in the middle of which a star is lying, so that these clouds tell us that it is a denser part of heaven, and there is a chorus[9] of little stars. But as Corsalo the Florentine[10] reports, that cross is twenty degrees distant from the South Pole, and travels round it as for us the Bear[11] or the Chariot[12] revolve in our view, but it is much brighter. There[13] are also six very brilliant stars, resembling the shape of a trumpet, of which Canopus is one among those that are mentioned. The diverse colours of the stars, and their magnitudes and brightnesses, and the blemish on the Moon, show that the substance of heaven is varied, and much the larger ones are settled in the noon-day belt,[14] with some fixed ones their equals in brightness. The greater Dog[15] is beyond the equinoctial circle, and everyone can see how much it shines. Canopus is accepted as large, and as less distant from the South Pole by 38 degrees. But at Alexandria the whole of heaven is visible, apart from 41 degrees. Much more is actually known about heaven than about the earth, because heaven is located up

Hipparchus onward, observers reckoned they could achieve this by eye, reckoning the brightness as a main indicator of size. See van Helden, *Measuring the Universe*, 24–25.

[6] This is Pietro d'Abano (1250–1316), Professor of Medicine and Natural Philosophy at Padua, author of the *Conciliator* (Venice, 1476), an attempt to reconcile Arab medicine and Greek speculative natural philosophy. He is also mentioned later, in Book VIII at 547 (1560).

[7] The remainder of this sentence with the two sentences following first appear in 1554.

[8] "temo," which classically meant the yoke-beam of a cart, chariot, or plough.

[9] "chorus."

[10] Andrea Corsalo was a traveller who reached Calicut in India in 1515 and Ethiopia in 1517, returning via the Yemen. He wrote two letters on his travels, and little else is known about him. Nenci (320 n. 4) traces this statement of Corsalo's to Corsalo's letter in G.B. Ramusio, *Delle Navigationi et Viaggi* (vol. I, 1563 ed., 177b). But as his note reports, there is difficulty in reconciling the detail of Cardano's statements here with his specified sources.

[11] Ursa major, the Great Bear, a well-recognised constellation near the North Pole.

[12] Not a constellation recognised under that name ("currus"), but probably *Auriga*, the Charioteer.

[13] This sentence first appears in 1560.

[14] "plaga." On the topic here see Philoponus, *De Opificio Mundi* 4. 12.

[15] Sirius is the primary Dog Star, and is the brightest star in the night sky; the other is Procyon, so called in Greek because it rises shortly before Sirius in mid-northern latitudes, and is the 8th brightest star in the night sky.

above, and is in perpetual movement. It is almost all known, for these two reasons; only 31 degrees around the South Pole were unknown to Ptolemy. So from the proof of Archimedes, the unknown is nearly one part in thirteen of what is known, or slightly less; hence only a fourteenth part of heaven was unknown to Ptolemy.[16]

&248 Someone will perhaps ask[17] whether the Moon's light is wholly dependent on the Sun. Indeed it is not, but it is much less dependent than the rest of the stars. It is in fact agreed that it is red in maximal eclipses, as fire may redden frost, and this is by then its own light. But since by night nothing seems from a distance dingier[18] than fire, and the flame looks red, then when the Moon gets in eclipse to us far away, it is evident that it possesses a light of its own brighter than any flame or candle. Suppose then that the Moon is extremely like a huge bright flame, on its own and without help from the Sun's rays. Then contemplate how with the help of the Sun's lights, as at full moon, the Moon is much brighter itself in eclipse—you will readily grasp that a Moon lit by the Sun's rays is brighter and clearer than the Sun itself, so that the eagle's eye, which it is said can look at the Sun with safety, does not dare to gaze at it. If you compare it to the Sun's radiance, the Prophet's word will certainly turn out true, that on that day the Sun, Moon, and stars are going to have seven times as much light,[19] since it is seen in heaven far over sevenfold more than is seen here, and are going to secure clear and fertile illumination. So everything shines and glitters above the ether, so much that if we also are there at the time of an eclipse and view the Moon, just as if there were countless brilliant candles lit, and our eyes were fixed upon them, the brightness would blind us.

But why do the stars seem to glitter?[20] Since heaven's substance is extremely rarefied, the rays that come to us are quite often shattered, but &249 always towards the perpendicular. This is why when the air moves, they seem to dither,[21] in the way that pebbles lying in the bottom of water seem to tremble because of the

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[16] Repeating this calculation with the use of integral calculus indicates that this result is notably accurate, the ratio of known to unknown being about 12.99 to 1. Three propositions of Archimedes (*De Sphaera et Cylindro*, 1. 40 and 41, and 2. 3) are relevant to the calculation and are mentioned in the text's margin.

[17] The remainder of this sentence first appears in 1560, and text of the material in 1550 and 1554 which it replaces is available as Appendix 1 in Nenci, 345, and a translation appears at the end of this Book III..

[18] "obscurius."

[19] Isaiah 30: 26: "Moreover the light of the moon shall be as the light of the sun, and the light of the sun shall be sevenfold, as the light of seven days, in the day that the Lord bindeth up the breach of his people, and healeth the stroke of their wound" (Authorised Version).

[20] "scintillare."

[21] "titubare."

movement of the flowing water. In the case of lights, this is called "twinkling."[22] The Moon and planets[23] do not twinkle, because the rays reach us with sturdy powers; they are much nearer to our location than the fixed stars.[24] The evidence that this is so is that when they twinkle more, and when even planets twinkle, which is abnormal, they predict the future correctly. Indeed, the middle air on high, when violently agitated, makes them appear to twinkle more rapidly and more obviously. When Mars is rather dim and red, it too twinkles, especially in the eyes of those whose vision is weak. This too actually fits with theory,[25] because those whose sight is weak convince themselves that the stars are twinkling more. On the same theory, the stars beyond the Equator twinkle more, being further away. Hence too the Great Dog,[26] which ought to twinkle less because of its brightness, twinkles even more because of its magnitude, being far away. And you will notice stars in one part of heaven twinkling more and in another less, very little at the summit, and in the case of those that are large and shine brightly, and those that are near the poles, for there the air moves less, and where there are no winds. Distant stars near the Equator twinkle a great deal, because the ether there moves along very fast, and so do little stars, and particularly if in that neighbourhood the wind blows continuously[27] upward. On the same reasoning, they also look much smaller and loftier than they really are. Contrariwise, pebbles in water and &250 fish look larger than they really are, and all water looks less when viewed from the side, and is reckoned shallower. This is why heedless and misguided people have run the risk of drowning.

Let us then demonstrate the reason for this, and for other points that need making: where things seen appear to be. Everything seen appears to be where the perpendicular to the thing seen, drawn from it above the medium which is the cause of seeing, meets the line through which the things seen appear, which always proceeds from the thing seen towards the eye. &251 First of all, let the eye be at A, and the thing at B will then be seen in the same medium in its position, because the perpendicular line is the same as the line [413]leading to the

[22] "scintillare."

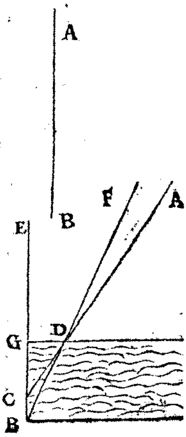
[23] "stellae errantes."

[24] Aristotle, *De caelo*, 2. 8, 290a18–22 (Loeb 187–89): "This is possibly the reason also why the fixed stars appear to twinkle but the planets do not: the planets are near, so that our vision reaches them with powers unimpaired; but in reaching to the fixed stars it is extended too far, and the distance causes it to waver."

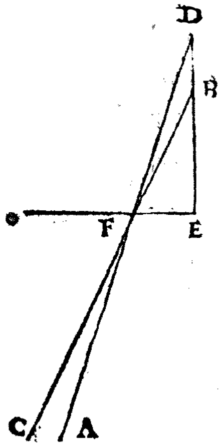
[25] "ratio."

[26] The constellation Canis Major, the "great Dog," is dominated by the star Sirius, the brightest in the night sky, which is no doubt the celestial object to which Cardano refers here. See also n. in Book IV at 270 end (1560).

[27] "perflet."



eye.[28] Again, let A be the eye in the air, B the thing seen in water, the perpendicular to the air be BE, the straight line BFA is bent from the perpendicular to the eye from F, so that BFC is drawn,[29] CF is extended to D, and B will be seen at C, therefore the depth of the water will appear as DE only. Again, let a star in heaven be D, let any heaven there is above be EF, let the perpendicular be DF, let the ray that runs straight be DFC; when it reaches at F a denser medium, that is, the air, it is bent towards the perpendicular,[30] and let DFA be the path along which the eye A sees the star D. Therefore let AF be produced in a straight line, and D will be seen at B, namely where two lines meet: the perpendicular DE from the thing seen to the medium, and the line BFA when it is directed from the part which touches the eye, that is, the part AF is a tangent to the eye.



But you will say, stars look much nearer than they actually are, if astrologers' accounts of their altitude are true; so they do not look higher up than they are. I accept that they are reckoned much closer, but for a different reason: because the interval between them and us is not appreciated; that is why, on contrary reasoning, all stars look larger while rising and setting than they do in mid-heaven, because the earth's size intervening brings it about that the eye reckons they are further away, and hence larger. Indeed too, a tower is assessed as larger than a forearm[31] by an eye that appreciates its distance, even if it subtends a smaller angle at the eye than the actual forearm. So this is why stars look close, because there is no body intervening between them and the eye &252 whose length the eye can appreciate, and consequently judge that they are far away, although, as I said, taking account of the medium[32] shows that they are higher. But what makes stars in the east and west look larger is the density of the air—not of the air in which we exist, but of the air far away from us. The proof must be that in cloudy weather stars also look much larger. This could not occur if it resulted from distance alone.

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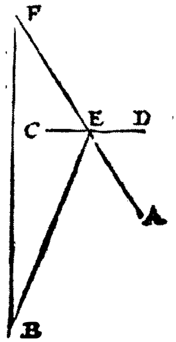
[28] As Nenci remarks here (325 n. 12), there is confusion between the text and the accompanying figures. It renders interpretation very difficult. Nenci's nn. 13, 14, and 15 should be consulted for a determined attempt to resolve the problems.

[29] "fiat."

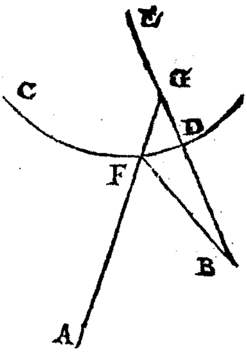
[30] "cathetus"—Greek κάθετος. The word is defined by Roger Bacon at one point (*Opus Majus*, 2: 550) as "the perpendicular drawn from the object to the mirror."

[31] "ulna."

[32] "medii ratio."



But I proceed to an account of where things seem to be, using examples. Let there be an eye A, a thing seen B, a mirror CD, and let BF be drawn perpendicular to the mirror's surface, assuming that surface to be extended, as it does not have to touch, and let BF be drawn reflected to A, so that the angle BEC equals the angle AED (this must be so in every reflection of a ray from a mirror of whatever kind). Then extending the reflected portion AE, let it join at F, and at that point B will be seen—experience confirms this. Also, in a concave[33] mirror CD, of which the centre is E, let the thing seen originally be placed at B, by the reflected ray BCA it reaches the eye, and clearly there will be a perpendicular EBF, which is met at the point F by AC reflected—and this will be the place where the eye A will see B (the thing seen) to be. It follows that B is not seen at F in the straight line, as it is in the previous figure.[34] Here &253 as a rule B will be seen not in the straight line of F to B itself, because the eye judges on comparison of some plane DK lying on top of the mirror, and yet the point F and the perpendicular are taken from the point E, which the eye neither sees nor appreciates.



Again, let there be G, which is seen in the concave mirror, and there will necessarily be a perpendicular GEF, and along a reflected ray GDA let it be seen by the eye; then the ray AD will meet the perpendicular at H; so the thing will be seen at H, and thus in the air outside the mirror—and it is extraordinary, but it corresponds nevertheless to experience.[35] But we have seen this going on much better in big mirrors, so that the occurrence entirely resembles a miracle. It goes on also in other kinds of mirrors, such as convex ones, spherical[36] ones, and pillar-like[37] ones. To a miracle is added a greater miracle, when something is seen which is not in the air at all, when a demonic imitation is projected,[38] as Vitellio[39] explained. We will set out its basis later, while dealing with light and illumination.

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[33] "cavo."

[34] The discussion here is incomprehensible, but might mean that in the upper figure the path from A to F is as long as the path from A to B, and so the object appears at its natural distance; but in the lower figure ACF is not equal to ACB, so it does not appear at its natural distance.

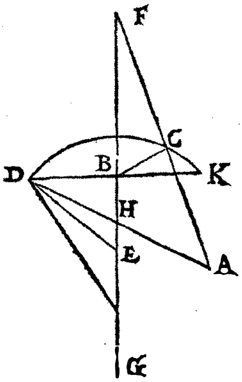
[35] The remainder of this paragraph first appears in 1554.

[36] "rotundus"—but it is not obvious in what way the convex and concave ones might not be spherical—they might even be conic, a type mentioned just below.

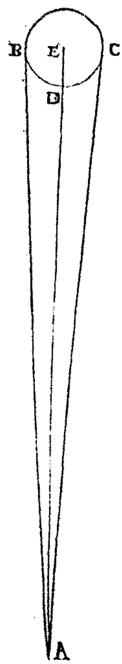
[37] Presumably cylindrical.

[38] "proposita."

[39] Witelo/Vitellio was probably a thirteenth-century Polish disciple of al-Hazen. Especially celebrated for his treatise on optics, he was also interested in demons, and



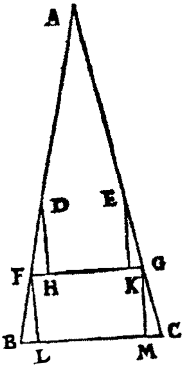
&254 So to get to the final kind: with a convex mirror again placed at CD, and the eye at A, and the thing B seen, there is a perpendicular to the mirror's centre BDGF, and a reflected ray AFG meets it at G, where B will be seen. The same theory shows the position of the thing seen in cylindrical and conic mirrors. So there are now three essentials for a theory of vision: the position of the thing seen, and that the thing is not smaller than the minimum visible at that distance; this — that is, the minimum — must be discovered for any distance; and that everything smaller than the minimum is as if it did not exist. [414]In this way it is not difficult to discover why stars, though appearing flat, are really rounded; for a line which from a point D is directed to an eye A is not less than the line BA, nor CA, unless in one line, which is less by DE.[40] Hence it comes about that since the line DE has no relation to DA, because of the excessive height of stars, so no difference is perceptible between AB and AC and AD, and so they are all seen as arising from the same plane, so BDC will be seen as flat, and so &255 all rounded things will appear flat when at a distance.



It will now be shown generally that there are very large stars, and that they are far away at the start, for the reason that they are very large. When then two lines AB and AC are drawn from the same point A, and are themselves equal, and two equal lines FB and FD are cut in them, and two more GE and GC equal to these, and BC and FG are drawn, and perpendiculars DH, EK, FL, and GM,

wrote a *De primaria causa penitentie et de natura demonum*, which does not survive. For further details see *DSB* 14: 457–62. In his *Peri Optikes*, 7. 60 is the proposition: "Possibile est speculum columnare vel pyramidale conuexum taliter sisti, ut intuens videat in aere extra speculum imaginem rei alterius non visae." And in 8. 11 is the proposition: "Locus imaginum formarum à speculis sphaericis concavis reflexarum, quandoque est in puncto reflexionis, quandoque est ultra speculum, quandoque inter visum et speculum, quandoque in superficie ipsius visus, quandoque retro visum." A complex proposition with a complex diagram.

[40] "nam linea quae a puncto D ad A oculum dirigitur non est minor linea BA, nec CA, nisi in una linea, quae minor est DE; eo fit ut cum linea DE nullam habeat comparationem ad DA, propter nimiam astrorum altitudinem, igitur non percipitur differentia ulla inter AB et AC et AD, quare omnes videbuntur ab eodem plano erigi, igitur BDC videbitur plana, omnia igitur rotunda procul plana videbuntur." The meaning is obscure, but seems to be that since B, D, C, and E are all far distant and not all in the same straight line (so that one cannot occlude another), no difference in their distances can be discerned. See also the next Figure.



then the angles L and H will be equal, because they are right angles, as are BFL and FDH, since DH and FL are parallel, and the line DF directly opposite and equal to FB directly opposite, and hence BL is equal to FH, and MC equal to KG on the same basis. Thus, since BC is greater than FG, as is obvious from the fourth proposition of the sixth book of Euclid's elements, it will be the case that BC can be increased so much that BL and MC, which always stay equal, are less in relation to distance, given the minimum quantity. So then, from the third proposition, with the difference between FB and GC hidden, it will be the case that they will be considered parallel. Vitellio attempted to prove this, which he did not clarify, and finally after introducing many errors he tried to prove it is false, evidently because BL would be less than FH; and this is false—&256 in fact, as I have shown, it is equal, and out of this equality BL itself has a less relation to BC than FH has to FG. This is sufficient to prove the proposition. Therefore since the Sun or the Moon or another star creates an almost equal shadow of the thing that is seen on earth, or on wood set facing its rays, whether the rays emanate from a single point or from a whole body, when this proof is altered, it is agreed that the proportion of the altitude to FG is not comparable. So since this occurs also in towers and vary large mountains, the lines GC and FB have to be parallel; hence the altitude of the star A is very great, and the star too is very great, because it is perceived from so far away with the magnitude that we see.

Judging from the shadow on earth in solar eclipses,[41] the diameter of the Sun is eleven, in the units of which the earth's diameter is two;[42] hence since the earth's diameter is twice five thousand[43] miles, the Sun's diameter will be eleven times five thousand miles, that is, fifty-five thousand miles. The proportion the Sun's body has to the earth is 166 and three eighths[44] to one, the circumference of the greater circle 173,000 miles plus 250.[45] The ratio of the earth's diameter to the Moon's diameter is 17 to 5, and so the earth's body contains the Moon's body nearly 39 times, plus two thirds.[46] The diameter of the Moon: 2941 miles.

[41] For explanation of this ancient technique, see van Helden, *Measuring the Universe,* 17 and Fig. 6.

[42] This is the long-accepted relation of the Ptolemaic tradition. See van Helden, *Measuring the Universe,* Table I (27). The subsequent data broadly correspond to those of that Table.

[43] The text reads "terrae dimetiens sit bis quinque M. passuum," which might well be taken to indicate merely ten miles.

[44] This is 55/10 cubed, very precisely.

[45] In fact $55{,}000\pi$ = 172, 788.

[46] This is a very credible calculation, since the volume varies as the cube of the radius or diameter, and the cube of 17/5 is 39.304.

The circumference of the greater circle: 9000 miles and in addition 264.[47] The altitude of these is also &257 available from Ptolemy's proof and is as follows: of the Sun from the earth's centre, six thousand and fifty thousand miles. Of the Moon from the same centre, 320 thousand miles plus 833. Cones of shadow from the same: 1340 thousand miles.[48] Hence, deducting 5,000 miles for the radius of the earth from each of these distances, there will remain the distances of the Sun and Moon, as well as of the cone of shadow from the earth's surface, or from our eyes. The distance of the Sun from the Moon when the Sun undergoes eclipse, or rather that of the solar orb from the lunar one, will be 5684 thousand Italian miles (the ones in this discussion), plus 167. And the observation that Philipp Melanchthon[49] appears to have made is marvellous: that whereas in the time of Ptolemy and Hipparchus the centre of the Sun's eccentric from the earth was 24 plus one fifth earth-diameters (i.e. 242 thousand miles), now it is only 18 plus two fifths earth-diameters (i.e. 184 thousand miles) from the same centre of the earth. Evidence, so to speak, of an ageing universe. But an explanation can be derived either from a change in instrumentation,[50] the arrangement of the solar heaven, or by observation of the equinoxes, which undergoes change, both in locations and in the Sun's magnitude, on account of which the equinox occurs rather faster than might be supposed. Since this was noticed by many people, it is ascribed to the Sun's magnitude. The Sun is &259 AB, its centre is C, the earth is DE, its centre is F, the line GHM is touching the sun and the earth, the apex of the cone[51] is M. So since GH touches the Sun and the earth, the angles G and H will be right angles, hence GC is parallel[52] to FH, and so the part GB

[47] $2941\pi = 9239.4$. The remainder of this paragraph along with the two subsequent ones and the first five sentences of the next one first appear in 1554.

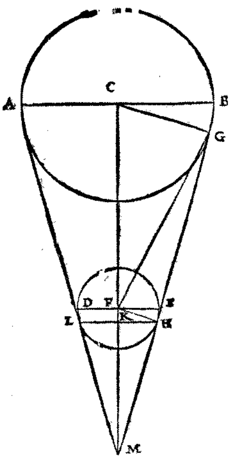
[48] Adopting values for the Earth's diameter of 10,000 miles, the Sun's diameter of 55,459 miles, and the distance of the Earth from the Sun of 6,050,000 miles, the cone of shadow down the sunlight *from the Earth* comes to 1,330,870 miles, close to Cardano's reckoning.

[49] Nenci (334 n. 26) has traced this reference to Melanchthon's *Initia doctrinae physicae*. Melanchthon (*Doctrinae physicae elementa*, Lib. 1 [92–93]) puts it that in the time of Ptolemy and Hipparchus, the eccentric was distant 48 Earth radii plus two fifths (i.e. the same as Cardano reports here), and now 36 radii plus 48 minutes. And he concludes, "Nec miremur, hanc nostram inferiorem naturam hominum et terrarum magnas habere mutationes, cum etiam in illa superiore, firma, et durabili natura, quasi rectrice fati, tam evidens sit mutatio."—no wonder that our human and earthly inferior nature undergoes large changes, when such an obvious change appears in that higher, firm, and lasting nature, one in control of our fate.

[50] "instrumentorum varietate."

[51] M is in fact the *apex* of the cone in the figure—can "conus" support that meaning? It can, because in Vergil, Ovid, Pliny and elsewhere, it means the apex of a conical helmet (*OLD*).

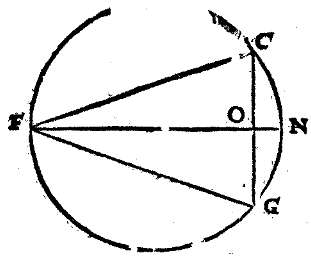
[52] "aequidistans."



is similar to the part HE. If therefore the ratio of GC to FH is known, the ratio of GM to MH will also be known, and similarly of CM to MF. And as CM is [415]supposed known by comparison to FH and CG, and H[53] is a right angle, GH and GF will be known, and the angle GCF known. And hence GCB,[54] and hence the arc EH is similar to GB, and hence the excess of the equinoctial day's length above 12 hours.[55]

Let EH be doubled on account of DL, let the arc LDEH be known.[56] Then GC placed beside this will be five and a half, and FH will be 1, and FC 1200 and CM 1468. Hence GM will be 1467 degrees[57] 59′ 23″. MH therefore will be 267 degrees 59′ 4″. Therefore the remainder GH will be 1199 degrees 59′ 30″; so GF will be 1199 degrees 59′ 31″ 30‴. So in the triangle CFG, one side CF is 1200 degrees. The second side, FG, 1199 degrees 59′ 31″ 30‴. The third side, CG, 5 degrees 30′. It is thus evident that FC and FG are almost equal, and that the ratio of either to CG is as 218 2/11 to 1.[58]

So let a circle be circumscribed round the triangle CFG, and it is clear that the diameter FN will fall in the middle, and will intersect CG in equal parts at O, FC and FG being equal. Then &260 deducting the square of[59] CO, which is 7 9/16,[60] from the square of FC, the square of FO will be left. What then is its side? It is FO, in degrees evidently 1199 + 59′ 49″. When the square of CO (which is, as I said, 7 9/16) is divided by



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[53] That is, angle GHF, or angle MHF, since both are right angles.

[54] Evidently the angle—the angle subtended at the Sun's centre by the arc GB.

[55] The Sun of the diagram being larger than the Earth and relatively close, it illuminates more than the half of the Earth represented by DE, the light reaching beyond E to H, and similarly on the other side; so the excess is measured by the arc EH plus a similar arc on the other side.

[56] The following passage is very obscure.

[57] "partium."

[58] From the subsequent figure, Cardano is not assuming that in the triangle CFG the angle at G is a right angle, which is not the case; the angle CGH is a right angle, EG being a tangent at G. But on this assumption, the calculation works out as stated in terms of degrees, minutes, seconds, and "tertii." What distance is represented by a degree is obscure.

[59] "quadrato."

[60] Cardano has asserted that FC = 1200 and CG = 5.5; the square of CO = the square of half CG and is as stated. The stated value of FO then follows.

this, ON will emerge: 0′ 23″.[61] Hence the whole of FN is 1200 degrees + 0′ 12″. Let us remove this[62] from everything because of the imperceptible difference; what will remain is FE, in degrees 1199 + 59′ 37″,[63] and CG, 5 degrees + 30′. Then with FN removed to the extent of 120 degrees and divided by ten,[64] FC will become in degrees 119 + 59′ 58″. So the arc FC is in degrees 179 + 36′ 00″. CN then is in degrees 0 + 34′ 00″. Hence CG is in degrees 0 + 48′ 00″. So the two arcs DL and EH are equal or similar to this one, because they are the double of the arc BG, to which CG is also double, &261 being in the circumference. So the whole arc LDEH is in degrees 180 + 48′ 00″, and therefore the day at the equinox lasts 12 hours 3 minutes 12 seconds, and the night 11 hours 56 minutes 48 seconds. And so it is at the equinox[65] all the time. And the equinox will be for us on the day before the one when the Sun enters the start of Aries,[66] and in addition on the second[67] and third day after the one in which the Sun enters the start of the zodiacal sign of Libra—that is, on the 8th of March and the 15th of September.

This corresponds beautifully to experience. But if the district is a little more elevated, as in the highest mountains, it gets so far ahead of the Sun's entry into the start of Aries that the astronomical calculation[68] is seen as false. Also, the 12th day of June is twice as long as the night. In our epoch, the first day of the equinox is the 10th day of March; it will be six minutes greater than the night.[69] In adition, there is the topic of collision of *illuminatio*, on which we will speak later.[70] I will not overlook a point also deserving astonishment: the higher the Sun rises, and is thus further from us, the more it warms us, because the angles are closer to right angles. And hence the winter is much colder, because the Sun is closer to the earth.

But why does the Moon alone undergo changing shapes, yet all the rest of the stars are rounded all the time? Does it change its shape because it is opaque, and such light as it has of its own is so much weaker than the Sun's as to be

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[61] This follows from the properties of the three right-angled triangles concerned.

[62] It is not clear what "this" is: the 12″? The passage is obscure.

[63] But FE in the figure is very much smaller than this.

[64] "et est diviso numero per decem"—sense unclear.

[65] "sub aequinoctio."

[66] Aries is the zodiacal sign; the Sun is nowadays supposed to enter Aries about 21 March and remain there till about 19 April, and to enter Libra about 31 October and remain till about 22 November.

[67] Cardano has written "imò *perendie* et post tertiam diem in qua Sol . . ." and "perendie" means "on the day after to-morrow," but I have assumed the translation given.

[68] "ratio."

[69] While obviously at the equinox day and night are equal, no doubt Cardano is thinking of minimal differences adjoining the exact equinox.

[70] In Book IV. The remainder of this paragraph first appears in 1560.

invisible at the part not illuminated by the Sun?[71] It is also a peculiarity of the Moon to possess a blemish, which prompted a great debate in antiquity, not a few people supposing that the moon has a share in elemental &262 nature, and is impaired[72] for that reason. Others suppose that it is an image of Ocean or of the earth's orb that is glowing back,as if from a mirror. But if it has an eternal body, we deny that it has any share of mortality. Nor can an image or some shape be visible all the same in a mirror so far away. So either it shows the blemish at a part which is porous,[73] as in mirrors where the lead has been scraped off, or else the patch is the limit of visibility; the Moon cannot be porous at a portion where it is visible, unless it is carried round by some movement, in such a way that it comes back to the same face by the opposing movement of a little circle and eccentric. But if there is a limit of vision, why does it not occur elsewhere? So it seems no surprise that this problem exhausted some people, and frightened off others—the [416]more modest ones. So if, as Calippus[74] and Eudoxus[75] thought, the Moon's motion is free, without little circles and eccentrics, the basis for the Moon's blemish will be discovered—that is, obscurity arising from transparence. Indeed, the part where the Sun's light is not reflected looks dark. But from transparency light is not reflected—it actually passes through. A range[76] of what is compact and what is rarefied clearly exists in heaven, as we can see in the Milky Way.[77]

There is another problem about the Moon, more evident to our senses: why with us a Moon full of lights makes a larger tide in the sea, but with the Indians an empty Moon[78] does it. The cause of the tide is regarded as the temperate heat and closeness of the Moon. At conjunction and full Moon, the Moon is in the

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[71] The remainder of this paragraph together with the subsequent one and the first sentence of the next first appear in 1554.

[72] "affici." The view of antiquity was that the Moon was a heavenly item, and hence should not be subject to generation or corruption as the elemental world is. So marks on its surface, representing imperfections, were a subject of anxious debate. The blemish on the Moon is also mentioned above in this Book at 247 (1560).

[73] "pervia."

[74] Callippus (thus spelled) was an astronomer of Cyzicus in Asia Minor and flourished around 330 B.C. He went to Athens and associated with Aristotle. He improved the theory of concentric spheres due to Eudoxus. Further details available in *OCD*.

[75] Eudoxus (c. 390–340 B.C.) of Cnidos (an island in the Aegean) was an outstanding mathematician and geographer and created the theory of concentric spheres to account for the movement of the heavenly bodies. For further details see for instance *OCD*.

[76] "varietas."

[77] On the Milky Way and the history of thought about it, see S. Jaki, *The Milky Way: An Elusive Road for Science* (Newton Abbot: David & Charles, 1973).

[78] I.e. presumably no Moon at all, between its last quarter and the new Moon.

same place—that is, closer to the Sun. But half way between full Moons,[79] it is nearer to the earth. In our regions, it is more temperate when full of &263 lights, because of the air's lesser warmth, but with the Indians it is so when empty of lights, because of the heat there. It raises things upward when it has reached a higher level, and is higher, as I said, at new Moons and full Moons. And with us it is more temperate at full Moon, but with the Indians at new Moon. That is the time at which it is changing its face, its light and power, through nearness to the Sun, not just on account of its light, but also on account of nearness to the earth. And it makes no difference if it is not higher, since the outcome follows the resemblance.[80]

But you will be saying, "Why are all the rest of the stars rounded, if the Moon changes its face through approach to the Sun?" This occurs either because its own light is as clear as the Sun's, but weaker, or else because it is porous in all directions. Therefore, on a well-understood theory, the stars are hugely distant from us, as I said; but because distance escapes our senses, they are regarded as small for that reason. Since the distance of towers is appreciated, and in addition we hold their size in our memory, we judge that towers are bigger than stars, since as well the angle they subtend at our eye is greater than that of stars. This is why towers look broader, if we see them from below, than if we could only look at the top part, because while we are looking at the base[81] we can see the distance. But how are these heavens linked?—if there is a single surface concave above and convex below, how in various parts can upper and lower heaven be moved? If there are two surfaces, something indivisible is being touched by something indivisible.[82] Yet there must be two, but they do not form a quantity—this was enough for Aristotle, to prevent a continuum being assembled from discontinuous items.[83] &264 [*wrongly numbered 246*] Another thing worth enquiry is, with the equant orbits[84] set beside the precise truthful basis of what is to be seen, whether those orbits happen to be twinned, as is said to happen with Mercury? And if they do, how can they be moved upward? Let the outside of an equant

79 "quadratis autem radiis cum Sole"; compare the similar phrase "in quadratis," found in Book II at 231 (1560).

80 "cum ad similitudinem res referatur."

81 "radicem."

82 Scaliger also found this difficult (*Exercitatio* 65 [244–45]), and resolved it by the masterly stroke of making the surface divisible "in potentia."

83 The remainder of this paragraph first appears in 1560.

84 This phrase, "orbis aequationis," evidently indicates a system of correction of circular orbits to accord with observation, such as the Ptolemaic system. In this, the "equant" is a point not at the centre of the circle round which a planet or other heavenly body rotates, nor at the Earth's centre, and the speed of the rotation is nonuniform, but varies in such a way that the planet sweeps out equal angles in equal times measured from the equant. For illuminating mobile demonstration of such phenomena, see http://faculty.fullerton.edu/cmcconnell/Planets.html#7d, visited on 15 May 2009.

orbit be A, the inside B, the innermost orbit be C, the outermost D, the outer centre B, the centre of the universe F, and the orbit outside the centre G, and amid these H is the centre of the concave exterior, and the convex interior. So it is clear that if the two upper orbits were linked together, and the two lower ones likewise, they could move upon the centre F, and so would raise an orbit above the centre. And if they moved upon the centre G, they would shatter the heaven of Venus and the Moon, between which the heaven of Mercury is placed; the whole surface of an orbit, moving upon its centre, does not violate &265the orbit it touches, since it stays in the same location. But a surface which is moved upon another's centre alters its position, and breaks the orbit it is touching. This being recognised, if A and C move as stated, they must move upon the centre F; hence they will carry along with them the orbits B and D, and so will be divided to no purpose, or the orbits B, C, and D will be virtually a single orbit, with the centre H, and this will make the whole assembly rise up, and it will relapse beside the position of the parts, as in the case of the Sun; the orbits B and D are glossy black separately, and in addition they move upon the centre H, and as they move bring down a semicircle of the orbit E; if they did not move separately, their detachment from E would be pointless. But if they were moving on G, they would break the orbits A and C—and so the orbit G moves on the centre O.

Further, this very great marvel, to get to know the seas and lands, which lie before our eyes, by the stars which are so far away—I leave out the fact that the ancients used to plough the seas with them as guides. This is the more remarkable, that when storm-driven into unknown seas or parts of the earth, they could make out where they were by the help of the stars. Joannes Baptista de ponte Vigo[85] required this of us. The reasoning runs thus: when the Sun's heaven has become clear by day, or another planet's by night, observe the altitude with a planisphere or armillary sphere[86] while the star is at its midpoint,[87] and deduct from this the declination of the Sun's position, if the Sun has reached between the start of Aries and the start of Libra. Or add the declination of the Sun's position, if it has reached between the start of Libra and the start of Aries, and deduct the result from 90, and you will have the latitude of the place, which those who recently cultivate India too knew how to discover.

&266 But in connection with the longitude, by obtaining the latitude with the altitude of the Sun or another known star by means of a planisphere, you will discover the hour of the day. Then, along with the latitude of the place, you will use an armillary sphere to enquire how the Moon's location appears; to that you

[85] Giovanni da Vigo (1450–1525) was surgeon and dentist to Pope Julius II, and an authority in his own time on the surgical treatment of gunshot wounds.

[86] "armillae."

[87] "meridiat"—only means "take a midday nap" in classical Latin.

will add or subtract the amount of the difference from the diversity of aspect, and you will have the true location of the moon at that hour; in connection with that, you will get from the Alphonsine Tables[88] the location and motion of the moon on the passing of individual days at present. So take into account[89] the difference of the locations of the Moon with an instrument and tables of observations, and with that divide the motion of the day; the differences of the hours and minutes will emerge; for individual hours reckon 15 degrees, for individual minutes a quarter of one degree, which you will add to the separation of the place from [417]the Canaries in the Alphonsine Tables, if the Moon's location has been found later with an instrument, that is, it has diverged more from the start of Aries than the location discovered by the Tables. Or you will deduct from the same the degrees and minutes where the place is in the Tables, so that the place found by the instrument gets more, and what remains or is assembled is the longitude of the unknown place from the Canaries, the longitude which you will seek out on the globe[90] along with the latitude, and you will know what your position is, and with which winds you can get back home. Since they do not know this, the historians of India[91] insert the latitude but leave out the longitudes of places.[92] In fact all those who make for either India[93] get much help from the declination of the Sun's course, and that of stars has been discovered by all those who deal with the Portuguese and Spaniards and are knowledgeable about this skill in navigation. &267 Furthermore, whether there is one universe, or more, or an infinity of them, or one infinite one, and whether there is something outside it, and whether it is eternal or generated, is dealt with in the books

[88] These astronomical tables take the start of their calculations from 31 May 1252, the eve of the coronation of Alfonso X ("The Wise") of Leon and Castile, and are presumed to be the fruit of his sponsorship. They aimed to enable users to calculate the position of planets for any given time and place. Such astronomical calculations were of great importance for navigation.

[89] "considera."

[90] "sphaera regionum."

[91] The "India" here doubtless means only the West Indies, which, being only recently discovered, commanded much learned attention. For instance, in Oviedo y Valdés, *Historia general y natural de las Indias* (Toledo, 1526), his very word "longitud" means simply "length," but he does include values for "*latitud*," which he calls "grados de la línia equinocial." Cardano's suggested procedure for determining longitude was evidently too difficult or precarious for practical use, and the problem remained unsolved till the advent of accurate timekeeping at sea; see Dava Sobel, *Longitude* (London: Penguin, 1996).

[92] This sentence first appears in 1554.

[93] I.e. the West Indies in the Western Hemisphere, and India and the East Indies in the Eastern.

De Aeternitatis arcanis.[94] But now we will discuss the light and the illumination[95] which flow from the stars.

Appendix 1, present in the 1550 and 1554 editions

Someone will perhaps ask why the Moon has a blemish. I will not explain this now, since we will deal later with the Moon's substance, and heaven's motion, then hail, snow, frost, winds, the abyss,[96] and the dew of heaven. At the moment I will explain here what are simply general things, as they relate to an account of heaven, taking a propitious start from the Moon, it being closer to us. Its light does not all depend on the Sun, much less does that of the rest of the stars.

[94] "arcanis"; on Cardano's work about *Mysteries of Eternity*, see n. to 5 (1560) in Book I.

[95] On the question of *lux* vs. *lumen*, there was a serious distinction between *lux* (here translated "light") and *lumen* (here translated "illumination"). D. Lindberg, *Theories of Vision* (Chicago: University of Chicago Press, 1976), 113, 124, 134, draws on Henry of Langenstein (ca. 1380) for the view that *lux* is a "natural agent, luminous quality of a bright body," while *lumen* is the "instrumental quality or species issuing from it." And similarly from Buridan (ca. 1295–1358) at Paris: "*Lux* has a fixed existence in the lucid body. *Lumen* is transparent, and does not terminate and bound its subject, and does not have fixed existence in it. Alternatively put: *lumen* is the species of *lux*, its image or representation in the media. It is *not* perceived, but is the agent by which *lux* is perceived." Putting it yet another way, *lux* is the power which a shining body has; *lumen* is the effect of that power. Presumably if the sun released *lux*, it would run out of it.

[96] "Hiatus."

[417] &267 Book IV
On Light and Illumination

All stars have their own illumination, movement and magnitude; and as a lesser illumination is covered up by a greater one, so its shadow is not in evidence. The Moon creates no shadow by day—it creates one by night. If the Moon is to shine, you will not see the shadows of the other stars. But when it is hidden, you will sometimes see the exceptional shadow of some of them, so much so that you would take the illumination of Venus coming through a window for the Moon's. So every star has its own illumination, since it has its own light; the result is that from a large supply[1] of stars mingling their illumination, the Milky Way is appreciated by the eye. This is facilitated by the compactness of heaven's substance and the rarefaction of that of the stars, as occurs in a comet, which has a tail or hair; being never changed, its presence in heaven and not lower down is accepted.[2]

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[1] "frequentibus."

[2] Jaki (*Milky Way*, 79) sees here two alternative explanations of the Milky Way, though it is not evident that Cardano, while mentioning them "in the same breath," saw them as alternatives, and Jaki refers to it as a "subclass of comets," a phrase which he repeats in mentioning Cardano's remarks on comets and the Milky Way in Cardano's *De Rerum Varietate*, which opens with much on comets (I.1: comets "nulla substantia propria constant, sed in coelo fiunt: neque vno solo, sed in singulis, quemadmodum et lactea via"). Cardano is however certainly inconsistent in writing of the "compactness of heaven's substance"—in Book III, at 248 end (1560), he calls it "rarissima"! On comets, Cardano appears to be anticipating Tycho Brahe here. Brahe in 1572 saw a new star and recognised it was not a comet; it "moved" with the fixed stars, and for Aristotelians, comets are generated in the air (see n. 3 below), not higher up. In 1577, a year after Cardano's death, he saw a notable comet that moved contrariwise to the fixed stars, and reckoned by measuring its parallax that it lay beyond the Moon and about a third of the way to the sphere of the fixed stars (*Dictionary of Scientific Biography* 2: 401–16; J. R. Christianson, "Tycho Brahe's German Treatise on the Comet of 1577," *Isis* 70 [1979]: 110–40). He then rejected the Aristotelian views that nothing new can be born in the heavens, and that comets are sublunary phenomena.

But how are rays traversing the void seen as refracted, since the Sun's rays are not subject to vision in the air? The same reason explains why where there is reflection of rays on earth, as occurs in &268 valleys, the heat gets much greater; if a ray penetrates, it is single only; when it is reflected, there are two, and when it is again reflected, there are three rays in the same place—consequently a great deal of heat is generated there. In the Milky Way, it is not two or three, but the stars being close and compact make a thousand reflections—and as there are many, there has to be a whiteness in the middle like milk, a feature even I have seen happen to be beautifully imitated by many candles, so that experience endorses the clear explanation.[3] Fire being kindled in concave mirrors is explained on the same basis, since very many rays coincide into a small space, though not in white material—it removes the basis on which they can ignite—they can do it because they coincide, but a white thing scatters and separates them. This is why a white fabric is readily consumed by fire, even by a spark, but is not consumed by the solar rays of a concave mirror. The same basis precisely exists in a crystal ball, and in a round glass bowl full of water. But just as in these the rays coincide head on,[4] so they do in the concave mirrors mentioned before; in fact the basis for burning or not burning is the same in both cases. When you have actually put a white thing in the way, the well-known[5] cone is clearly expanded, and so cannot burn anything. Because it is expanded, it is also appreciated by the eye.

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[3] Cardano does not mention the Aristotelian discussion of the explanation of the light from the Milky Way. Aristotle's predecessor Anaxagoras, holding the Sun to be smaller than the Earth, believed that there was an infinite shadow beyond the Earth, in which the light originating from the items in the Milky Way was visible, because the Sun's light did not interfere with it; but the other fixed stars were visible by reflection of the Sun's light. Aristotle did not agree, but regarded the Milky Way and comets as existing at a lofty sublunary level, yet not so distant as the sphere of the fixed stars. See Aristotle, *Meteorologica* 1.8, 345a11–346b15; Loeb 57–69. Cardano does not appear to endorse this distinction of levels.

[4] "ex adverso."

[5] "ille." In traditional "efference" visual theory dating back to Euclid (see Lindberg, *Theories of Vision*, 12 and elsewhere), the "well-known cone" is the cone of "rays" proceeding initially *from* (only later back to) the eye, which is regarded as the vertex. The base of the cone lies at the seen object. With this reversal of the modern view in mind, look at a lit light bulb, conceiving your eye as the vertex of a cone and some of the light bulb as its circular base. Then place some thin paper in the way. The paper gets diffusely lit by the light bulb, and the patch of light is now undefined and occupies much more of the field of view than the light bulb did previously. Galen's view was that the cerebral pneuma (i.e. spiritus) emerged from the eye and then, after contact with the lit object, returned on the same path through the eye to the brain. See R. T. Siegel, "Principles and Contradictions of Galen's Doctrine of Vision," *Sudhoffs Archiv* 54 (1970): 261–76, and for a full detailed account of this view, O.-J. Grüsser, "On the History of the Ideas of Efference Copy and Reafference," in *Essays in the History of the Physiological Sciences*, ed. Claude Debru

But why does concentrated illumination (especially the Sun's) heat up what lies below, when the Sun is not reckoned hot? In fact I would not hesitate to suppose that the Sun is hot, since I would reckon nothing else hot with that kind of heat, a point made earlier. Indeed, decay heat and fiery heat do not generate, &269 but destroy; it is the heat of Sun and stars that generates. The heat of things that are without life is nothing in actuality, and cannot be perceived by the sense of touch—the Sun's heat is available[6] to the sense of touch. But the heat of animate things is not like this, since it needs fuel, and the heat of stars is hardly like that. However, if you care to inspect Aristotle's views, you will say that while air and water strive to receive this illumination, they are put in motion and scattered, through a natural faculty by which light things rise and heavy ones descend. Also, the heat that was already in them in potentiality is aroused and conveyed to actuality. Water grows hot from the air—air that possesses no heat from water. Hence its upper surface is either the only part that is hot, or is particularly hot. Rarefaction follows upon this movement, and heat follows the rarefaction; how this occurs was explained above. In fact, heat, motion, and rarefaction are one another's cause, in a shared cycle; indeed, subtlety is a cause of heat—and while the heat is consuming,[7] it is a cause of movement. But in addition, movement is itself a cause of subtlety, for movement thins out the parts, by striking them together. Because a rarefied substance receives the great power of the ray, it gets hot, and a hot thing arouses movement by attraction and dispersion. This interchange[8] provides life in animals, and is very obvious. Indeed, we explained above that a cold thing is nothing but one that lacks heat and does not receive any. So it is impossible for a rarefied thing to be quite cold, and therefore the ray itself or the illumination appears to be the substance of heat—and this would be enough for us, who pursue the explanations[9] of things only so far as they help to &270 reach the truth of experiences. [418]So whether you refer to the rays of the Sun or stars as hot in themselves, or as not hot but as producing heat, we will be equally content. It is my view that heat is the substance of the ray of a star—yet as it is inseparable from illumination, it is not a quality capable of corruption. In fact the heat that is taken up by elements or mixed items is not celestial, but only a celestial image. So as stars have their own light, in the same way they have heat, to which no cold is contrary, but cold is simply deprivation of heat.

(Amsterdam: Rodopi, 1993), 35–54. Alhazen (al-Haytham), an Islamic mathematician (965–1039), was the first to show clearly that vision results from light reflected from an object to the eye, but his work was little known in Europe till towards the end of the 16th century. See N. el-Bizri, "Ibn al-Haytham, or Alhazen," in *Medieval Islamic Civilization: An Encyclopedia*, ed. J. W. Meri, 2 vols. (New York: Routledge, 2006), 1: 343–45.

[6] "subiicitur."

[7] "depascitur"—might mean either "is consuming" or "is being consumed."

[8] "vicissitudo."

[9] "rationes."

But you will say, "If movement is the cause of heat, why is it that in bed and at complete rest, we are hottest?" In fact movement stimulates heat, but it chills when it exposes us to colder air through change of position. And so in winter major movement heats us up, but slight movement chills us. But you will say, "Why do people at rest get cold, but are warm in bed?" Down[10] seems to make a contribution, or a feather bed[11] or wool, which are kept in beds. But the outstanding cause is that the air is not changed—the air that is gathered under the coverlet[12] is what touches us. The air is in movement round people at rest but not in bed. A human being is chilled by movement in two ways: both because the warmed air staying round us moves away, and because movement, as mentioned, chills the air.[13]

But I return to the account of light and illumination. Illumination, then, is the representation[14] of light, which has the substance of brightness in itself and of heat so closely bound to it that it is almost nothing else. This is why the brightest stars are also the hottest, such as the Sun, both Dogs, and Jupiter. So illumination and brightness and &271 heat are not three things, but one, in a combination of different things, taking on different names and even a diverse image and representation. But the light from which the illumination flows forth is a quality from the third kind of quality.[15] And just as illumination is made from light in a transparent body, so colour is made from colour in an opaque one. All these things produce their own appearance—people walking in meadows seem to have green faces. So since a potent colour can do this in the open air, what will it do in gloom?—where only the light is defective, and imbued with a colour from elsewhere. This is the way in which a lantern burning only alcohol and salt renders faces as pale as death, provided all other light is absent—I have experienced this. And on the same basis, if green oil is ignited into green lamps (as people

[10] "pluma."

[11] The word here is "cottum"—a very late Latin word, with an alternative form "cottus," both to be found in DuCange 3: 599, with citations indicating that one lies on it in bed, and it became converted to "couette" in modern dialect French, meaning a feather bed.

[12] "culcitra" classically means "mattress" (*OLD*, though *L&S* is a little less specific) but the sense seems to require some sort of padded coverlet here.

[13] See, as cited by Nenci, Pseudo-Aristotle (*Problemata*, 8. 16, 888b21–26; Loeb 187–89): "Why do we get colder in the winter if we run than if we stand still? Is it because the air which surrounds the body when standing, once it has been warmed, causes no discomfort, but when we run, fresh air continually meets us which is cold, and for this reason we get more chilled when running? Moreover, the air becomes colder when it is moved; and this occurs most in running."

[14] "similitudo."

[15] Aristotle (*Categoriae*, 9a28–b33; Loeb 67–71) under "third kind of quality" mentions hot/cold, black/white, sweet/sour, colours—but *not* light/darkness. See Nenci, 353 n. 8 for the text.

say occurs when an unripe grape is kept in the oil so long that it ripens under the Sun), everything will look green. Besides, an enclosed glass lamp conveys a powerful colour in all directions towards what it meets[16] when the illumination in it is lit. The strong colours are black,[17] green, white, red, blue-green or "heavenly." Fire can achieve this effect quite distinctly, and do much more—for instance to reproduce images of snakes. Its potentiality ought to be like this, and ought to be assisted by its own smoke in reproducing the images of things.[18] Thus illumination can alter colour, size, and shape, so that tree trunks look like snakes, yet cannot take on a shape from elsewhere. But in fact, human beings cannot look as though they were headless, as people say, nor as if they had a dog's head—&272 if illumination conceals heads, it conceals the rest too. Nor can it alter the form in accordance with the illumination's nature, if "figure" is understood instead of form. That it should be hidden by violence[19] either does not happen at all, or is very uncommon. Not only their particular characteristics seem to be altered, but also general characteristics accessible to the senses,[20] and some of these appear altered more, or more easily, such as size, number, state of rest or motion, and figure. Some actually look rounded when in square openings, because they are not sensed on their own, nor do they imprint themselves on sense so precisely or so strongly;[21] illumination and colour are the particular characteristics for vision.

[16] "ad obiectas res."

[17] "niger"—shiny black. Matt black is "ater," strictly speaking.

[18] The remainder of this paragraph first appears in 1554.

[19] "vi."

[20] "communia sensibilia."

[21] This problem, that when you look at a round object such as the Sun through a square grating, it still looks round, is addressed by Pseudo-Aristotle, *Problemata*, 15. 6 (Loeb 1: 333–35) and 11 (Loeb 1: 341), where a detailed geometrical explanation is offered, rather than the general remarks here; the rays from the object are treated as a cone with its apex at the opening, and continue to the eye in straight lines as a second cone from the opening onward. Presently (292 [1560]), Cardano addresses a subtly different question: the image of the Sun in eclipse is projected through a grating onto a plane surface. This phenomenon is discussed by M. Minnaert, *Light and Color in the Outdoors* (New York: Springer, 1993), 5.

But we will deal with colours at their own place—now the subject is illumination and representations.[22] Illumination[23] is, as has been mentioned, the image of light in a transparent body. Transparency is threefold: something equal, something unequal, or diverse in its individual parts, and something on the surface only—mirrors are like that. We call this the sheen.[24] In an evenly transparent body the illumination proceeds in a straight line—in an uneven one it is broken up, and reflected by the rarefied medium. So it is accepted in this connection that there are only three kinds[25] of illumination: direct, reflected, and refracted. Direct illumination shows things as they are; refracted illumination shows them altered; reflected illumination shows them dimmed, as from mirrors. Sometimes these are mingled, as when illumination is simultaneously refracted and reflected by rather thick glass with lead facing it.[26]

Then the best mirrors are made of steel or silver,[27] not from glass or crystal, though people believe otherwise. But the reason why the glass ones &273 are thought better is that metal ones are easily spoiled. Metal ones are more precise,[28] glass ones are longer-lasting if they do not get broken; that smooth sheen is not so easily banished[29] in glass, since on the drier material it does not adhere so simply. The reason for the adhering is moistness: the bond of adher-

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[22] "repraesentationibus." This word also occurs in Book I (4 [1560]) and is difficult. Cass ("First Book," 141, n. 4) points out that later Cardano promises to discuss 24 kinds of "repraesentationes" in Book XVIII, but in that Book does not use the word at all; he has replaced it by "visiones." Julius Caesar Scaliger is critical: he holds that "repraesentationes" comprise "species" and "imagines," and derive from "accidents" (in the philosophical sense): *Exotericarum Exercitationum liber quintus decimus*, 8. Schütze, *Die Naturphilosophie in Girolamo Cardanos* De subtilitate, 30 also discusses the word and translates it by "Vorstellung."

[23] Material from here to [A] on 274 (1560) first appears in 1554.

[24] "nitor."

[25] "species."

[26] Lead was sometimes employed as the "silver" of mirrors. Here it may be that the thick layer of glass was itself "silvered" with lead, which would obviously lead to a combination of reflection and refraction with any oblique ray.

[27] Presumably sheets of one of these metals, not glass coated with one of them. Mirrors were always smooth plates of metal, until glass mirrors appeared first in Venice from the fourteenth century (C. Singer et al., *History of Technology*, 7 vols. [Oxford: Clarendon Press, 1957–1978], 3: 238). As backing for the glass, tin with mercury was used from about 1515 (ibid. 3: 40), and alloys which might contain arsenic from 1530 (ibid. 3: 29). Metal plates continued in use for some purposes for a long time thereafter. At this point I have ignored the words "de quibus inferius agetur, docebimus," which are clumsy and omitted by Nenci.

[28] "exactiora."

[29] "Non . . . extinguitur"; but some word meaning "is not so easily imparted to . . ." would seem more apposite.

ing things is present in moistness. But things that reflect[30] are impaired in their figure, and things in which the illumination is broken up. And so concave and convex mirrors, as well as non-uniform media,[31] return distorted[32] images. This leads us to the reason why images are returned less from earth than from walls, and less from walls than from mirrors. For illumination is only made from light in a transparent medium;[33] things that are not glossy are not transparent, and so the illumination fails; actually every solid transparent thing has a sheen, and everything with a sheen is transparent.[34] Therefore statues give out light even under water. Hence the well-known Vergil quotation:

> I am not very misshapen—I saw myself recently on the shore, when a calm sea rested from the winds. In your eyes, I will have no fear of Daphnis, if the likeness never deceives.[35]

It appears that rays are reflected by everything, because there is some sheen in every solid body. But the remarkable thing is why heat and rays penetrate more through solid, thick, and transparent things than through opaque, rarefied, and open-structured things. Transparent things are not full of channels,[36] because air is continuous, and in glass and crystal these straight channels cannot be present, because it would not stay together[37]—the rays are straight.[38] Water does not tolerate channels in it, although it is transparent. So everything that &274 accepts an image of light is not cloudy, but is referred to as clear and transparent. [419] Illumination is in fact not a body,[39] but the image of light, which has no need of channels nor of heat; heat is more corporeal. Because rays are received in a solid, heat is received too.[40] [A] But there is considerable uncertainty about how it is reflected by the stars—if illumination is reflected from a star, the star ought to

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30 This verb is active.

31 "perspicilia non aequalia"—the translation is rather anachronistic!

32 "falsas."

33 But the word "transparent" as translation of "perspicuus" may leave something to be desired; it appears from the context to mean rather, "translucent."

34 The reasoning here is opaque. Cardano has indicated just above that metals can have a sheen, and indicates just below that statues can emit light, and that rays penetrate more through solid thick bodies..

35 Vergil, *Eclogues* 2. 25–27; nowadays "informis" is read instead of Cardano's "deformis."

36 "meatus."

37 "consisteret."

38 The sequence of thought is unclear.

39 "Non enim lumen corpus,"

40 Aristotle (*On Coming-to-be and Passing Away*, 326b10–13; Loeb 247–49) denounces the pore or channel theory as superfluous, but says nothing there about heat.

be solid, but if it is, why is it not shattered by its motion,[41] and does not exhaust the illumination by which it is moved? As it does in the animal body too, the soul ought to move of itself and with eagerness; but in us this eagerness is lacking, because all there is there[42] is power,[43] which is poured out from the heart where the soul dwells. In heaven, where there is soul everywhere, there is eternal eagerness, and that is why the soul is not exhausted by the will, because it needs no bodily help, any more than the heart does, since the soul is in it—but the soul does have the look of exhaustion.

Since heaven is never at rest, and has soul present everywhere, it can never be wearied. But the problem is not so clear about the Moon's orbit which carries the ether along with it—it ought to get wearied. It is better to say that this feature[44] is present of itself in the whole of the ether, so that each part can be carried round in a circle from East to West, and when individual parts get displaced, they will return of themselves. This is a problem for us, who have supposed that the universe would have an end, and had had a beginning, in books *De aeternitatis arcanis.*[45] But possibly we will say that the ether is carried round in accord with the will of the primary heaven, as water is carried round in accord with the Moon's motion—not through the nature of an element, but in compliance with &275 higher entities[46]—or else because this is enough to conserve motion without effort, but its start could not occur without work.[47] But this motion has had no start, since it is eternal.

Enough about this; let us return to the account of light and illumination, where anyone will reasonably enquire why the air is bright and clear before sunrise and after sunset, a time called the time of twilight. This evening occurrence has kept the name of "twilight," but the morning one has changed its name to "dawn." Vergil[48] recalls this in twelve clear examples. Quoting the first is enough:

> Dawn, glittering in her saffron apparel, had left the Ocean behind, and was aglow as her twin-yoked horses drew her along. The glossy white sphere

[41] Evidently Cardano is contemplating the diurnal rotation of the sphere of the stars round the Earth.

[42] "ibi"—presumably in our bodies.

[43] "vis."

[44] "hoc" ; the reference is unclear.

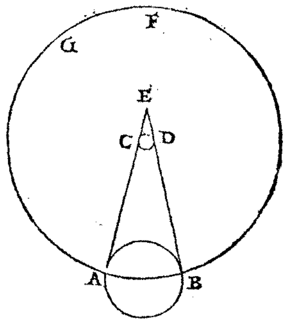
[45] This is a reference to Cardano's own work, *On the Secrets of Eternity*, on which see n. to Book I at 5 (1560).

[46] "superiora."

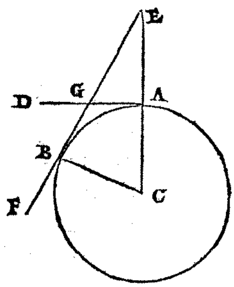
[47] "labore."

[48] Cardano is in error; this is not from Vergil at all, but from poem 579 (attributed to Asmenius) in the *Anthologia Latina* (ed. Buecheler, 2: 579).

bathed the pole in glinting light, and a bright beam flashed forth as the Sun arose.[49]



&276 So when the Sun's rays are blocked from the earth, they bring no brightness unless they are reflected from some place. In fact, at the middle of the night, let the Sun's heaven be ABF, the Sun AB, the earth CD, let the tangents ACE and BDE be drawn converging at F; so everything that lies under the heaven ABF and above it is lit by the Sun's illumination, except the triangle CDE, and yet the parts F and G are not clearly seen, because the Sun's rays penetrate without being reflected. But the Sun is not able to create twilight through its size—firstly because its rays would be seen, and we would see the Sun itself; and secondly, as we have shown, because of the very great altitude, the lines CE and DE would be made almost parallel.[50] So twilight occurs, since the part lying above the earth under the point E, that is, under the earth's shadow, being compacted by vapours receives the Sun's rays and reflects them to us.



So let us observe the Sun lying on the equinoctial circle, and it starts the twilight[51] 19 degrees before its rise, that is, about an hour and a quarter before the rise of the Sun itself,[52] and it is evident that then is the first time that a Sun's ray that illuminates the air reached the earth. For if it did not touch, it would meet vapour from on high, be brought to earth at a lower point first, and so it would initiate twilight before the specified time.

This being established, let a circle be set up with reference to the earth, with a centre C, a tangent AD,[53] the top of the vapours E, the position of the Sun's ray F, and where it cuts AD, let G be placed. Since the Sun's distance is very great in &277 comparison with the earth, the angle FGD is as if it were in the centre C of the earth, so that it is 19°, and so therefore is EGA, being in the centre of a circle. But A and B are right angles, so since E is common to the two triangles CBE and AEG, they will be similar. Therefore the

[49] "Aurora oceanum croceo velamine fulgens
Liquerat, et biiugis vecta rubebat equis;
Luce polum nitida perfudit candidus orbis,
Et clarum emicuit Sole oriente iubar."

[50] Text present here only in the 1550 edition is available as Appendix 1 in Nenci, 421.

[51] Yet just above it was explained that the morning twilight is called dawn!

[52] This is correct—360° = 24 hours, so 19° = 1 hour 16 minutes.

[53] AGD appears to represent (rather cryptically) the line of sight to sunrise.

ratio of the sides is known, but as mentioned, BC is five thousand miles.[54] Therefore AE is 288 miles, and the vapours rise to such an altitude.[55]

Look, can you see how far the subtlety of human genius can reach? I am aware that Vitellio[56] was deceived and related that they rise only to 52 miles, though they rise five and a half times as far as he said. But since he reduces the earth's circumference and creates even larger paces to some extent, it is not possible to bring &278 it[57] to a fourth part of the appropriate altitude. But if twilight is brought to its highest during the two hours before the day, there will be an angle C in the circumference equal to G, 60°, and E 120°, so that the line AE, the altitude of the vapours, will be 772 miles, and this is the maximum interval to which vapours can ascend from the earth.[58]

So rainbows, partial rainbows,[59] gaps in heaven, cannot exist at any greater height, nor can triple Suns, twin Moons, and much [420]less, showers, hailstorms, snowstorms, hoar frost, and anything that originates from vapours. But we must reckon that this altitude is different at different places, but barely greater than the stated number of miles. So let us suppose that we, who live about 68° from the tropic of Capricorn, when the eye is in B at Milan—the point that appears under the Tropic of Capricorn is E. It is agreed that the ratio of CE to CB is approximately 8 to 3. Since then CA is equal to CB, the ratio of CE to CA too will be 8 to 3. Hence AC to AE is as 5 to 3, and so AE is 8000 miles, plus 333 which I do not take into account. It is sufficiently established that the place which should be seen by an inhabitant of Milan under the winter circle is more than ten times as far from earth as the height of the vapours reaches. But comets are seen there by us, so they do not arise from vapours. Yet not higher up in the ether either, since there is no inflammable material there. But if you suggest that the stars' power seizes moistness and drags it up there, although the place is higher than the general location of vapours—the first obstacle is that most comets get

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54 The earth's radius.

55 I am not sure what methods of trigonometric calculation were available to Cardano, but the calculation is correct: the angle AEG is (90°—19°) and hence AE = 5000 (1—sin 71°)/sin 71°, which is 288.1.

56 For Witelo see n. in Book III at 253 (1560). Nenci cites here Witelo, *Peri Optikes*, lib. 10, prop. 60, 283a; this proposition is entitled "Summorum vaporum consistentiam ad quantum possint elevati pertingere, possibile est inveniri," and proceeds from observations to be made at twilight to argue by complex reasoning that these vapours extend 52 miles upward.

57 The altitude reached by the vapours.

58 While I cannot interpret "and E 120" just above, to obtain the stated result the angle E (I.e. AEG, not the angle C) must be 60°. But Nenci, 359 n. 18, cites Pedro Nuñez as remarking that Cardano's diagram is wrong, and the first light would be seen at G, not at E; "who ever saw twilight above the top of his head?"

59 "Virgae incendia"; *OLD* supplies the meaning "imperfect rainbow or similar phenomenon," citing Seneca. Also see n. 94 below.

beyond the &279 second month, and some are not even over in the third, and the whole apparatus[60] of earth would not be enough for this conflagration. It was in fact shown previously that a fire never exists permanently in the same material, but needs fresh all the time. This fire is usually a star with a tail, and is in the ether, which is why it is no smaller than the Moon.[61] It is quite impossible that so much material should be ablaze and last for three months. Furthermore, some are less conspicuous, being hidden before sunset, or do not move, and neither of these types has yet been seen. Apart from that, there are many aspects that show the absurdity of this opinion, and I avoid them, like the observation of Albumasaris,[62] that a comet was seen above Venus — and Venus is much higher than the Moon. But it is quite easy to discover whether there is a comet in the region of the elements, or one coming about in heaven: if it possesses greater diversity than the Moon, it must be in the region of the elements; but if less, it must surely be in heaven. You see how human subtlety can proceed to unveil heaven's secrets by using modest devices. Common features of all comets is that they move with a triple motion. One is from East to West, like all the rest of the stars over the twenty-four hours. The second is from West to East, a little more or less than one degree of heaven, almost resembling Venus. Since a comet appeared in 1532 on the 22nd day of September and passed away on the 3rd of December, it moved forward in 51 days from the 5th degree of Virgo into the 8th of Scorpio; &280 this brought it about that it moved forward only 63 degrees of the zodiac according to longitude in 71 days, less in fact than one degree per day.[63,64]

This makes plain that it could not be under the Moon, for then it would be moving faster than the Moon, through the movement of the primary orb. It is accepted that in 24 hours the Moon moves back by three degrees in relation to the primary movement. Pliny[65] reckons that a comet is not visible beyond 80 days, and takes at least seven to become hidden. Hieronymus Fracastorius, the author of the earlier example, reports to a similar effect in his book on *Homocentrica*, on the eighth day of September, 1531 — that there was a comet a little to

[60] "machina."

[61] "quo fit ut minus Luna non sit" — it looks smaller than the Moon, but since it is farther away, it is not in fact smaller.

[62] Or Albumazar; Arab astronomer, died in A.D. 886. See C. Burnett and K. Yamamoto, *On Historical Astrology* (Leiden: Brill, 2000).

[63] Girolamo Fracastoro in his *Homocentrica* (*Opera omnia . . . pars posterior*, 214) reported the paths (not the parallaxes) of several comets, and worried over whether they could be supralunary yet follow similar paths: "Si vero non sit sub Luna orbis ille, difficulter quidem rationem assignare poterimus, cur fiat ut cometes omnes motum illum in latitudinem habeant."

[64] Nenci (34 n. 41) feels that measuring distances of comets which are far from dense and are virtually diaphanous is "legato," i.e. awkward.

[65] *Nat. Hist.* 2. 22. 89–90.

the east of the Sun, that is, adjoining the 24th degree of Virgo; and around the start of October, when Jupiter was in the third degree of Scorpio, it grew near to it.[66]

In a single month (he was careless about explaining) the comet traversed around 40 degrees in longitude, that is, moved forward from the 22nd of Virgo to the second or third of Scorpio, a motion barely different from that of Venus or Mercury. The third movement of a comet is the largest in terms of latitude, so that unless he is misled, now one is transported with incredible speed to the north, now another to the south. These movements occur when comets get close to the poles, for then a limited alteration of location in relation to the zodiac changes the latitude considerably. Another general feature of a comet is that its tail always faces precisely away from the Sun; for instance, when the Sun goes down, the comet has its tail exactly to the east, and we can see it on &281 individual days during the dark phase of the Moon.[67] A third feature is that mostly it accompanies the Sun in longitude, appearing only at twilight, yet not always. Hence it is quite clear that a comet is a round mass[68] in heaven, which is seen to be lit by the Sun, and while the rays pass through it, they create the likeness of a beard or tail. This can therefore happen in heaven, if there is generation there—but if this is not admitted,[69] what must be said (and is quite true) is that heaven is full of numerous stars, but not quite tight-packed; for when the air dries up and is thinned, or also from other causes, it presents itself to our eyes.[70] There are times when Venus is visible at midday, and it is agreed that it has not been created *de novo*. Hence it comes about that when the air is drying up, the seas are much stirred up by storms, and very often huge blasts of wind follow on—and nobles and princes, being dried up by anxiety, sleeplessness, fragrant foods, and potent wines as well, pass away. Through this cause also occur reduction of waters, death of fish, infertilities, changes of laws, mutinies, and even through this cause occurs overthrowing of kingdoms—all these, as I said, from the excessive rarefaction and dryness of the air, so that though a comet can be a sign of them, it is not their cause at all.[71]

There is less uncertainty about the rainbow, a more frequent event, and evidently occurring in the region of vapours. A drop of water examined against the Sun displays many colours, all vivid; similarly a rainbow occurs out of a

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66 A comet appearing at this date too is mentioned by Fracastoro.

67 "in obscura Lunae parte."

68 "globus."

69 An Aristotelian could not admit generation or corruption in the heavens, although this was refuted by Philoponus in the sixth century.

70 Possibly he means that on a very clear night the background of the sky, apart from discernible stars, looks faintly bright.

71 Pliny (*Nat. Hist.* 2. 22, 23 and 59) in his account of comets repeatedly remarks that they *indicate* some present or future circumstance, but not that they cause it.

dense dewy cloud full of droplets. &282 Everything dim looks dark; evidence is shadows, which for this reason all look dark.[72] And when a wall has received double rays at the same time—direct ones from the sun and reflected ones from water—the effect is that part of them is blocked off from the person. For the upper shadow is illuminated by the rays of the Sun, and so is not so dark. But when the dim is illuminated and has got shiny,[73] it changes over into colours in proportion to the supply of light.[74] A cloud is dim, and drops of water are shiny, so they produce colours according to the diversity of the light. [421]Since the inner circle is closer to dimness, it looks blue; the middle one, which is more light, looks green; the outer one, the biggest one, illuminated by more ample light, is saffron-coloured. Purple and greenish purple[75] are not main colours, but because of changing illumination, there is transfer from one colour into another, and as the boundaries come together, other colours have to appear faintly in the middle, as they do in pictures. The centre of the Sun, of the eye, and of a rainbow are in one straight line.[76] Perpendicular rays are reflected in this way too from a concave film,[77] and though the film itself is not rounded, yet the rays alone are so, being reflected from the rounded part, because they alone are perpendicular. They reproduce the image of the Sun; since that image is weak and weakly

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[72] Two sentences here first appear in 1560.

[73] "politus."

[74] The theory of the rainbow in antiquity is discussed by Carl B. Boyer ("Refraction and the Rainbow in Antiquity," *Isis* **47** [1956]: 383–86), who explains that Cardano's source Witelo sets out the role of refraction, but Grosseteste (ca. 1170–1253; see n. 79 below) had already introduced a refraction theory. And indeed Olympiodorus, a commentator on Aristotle, had also done so long before (ed. G. Stüve, *CAG* 12. 2 [Berlin: Reimer, 1900]). The Latin word "refractio" had sometimes been used in antiquity to mean "reflection," so that care is required in interpretation. But Roger Bacon (ca. 1210–1292) was clear enough: "If however, we consider that reflection takes place in the same medium, and refraction in different ones . . ." (*Opus majus*, 1: 141).

[75] "xanthus," a Greek word normally meaning "yellow-red, auburn, golden" and corresponding to Latin "fulvus," is not found in *OLD* nor *L&S*, but Witelo (*Peri Optikes*, 10, prop. 67, 287b-288b), cited here by Nenci (367 n. 31), wrote, "Color vero xantus, qui inter colorem viridem et colorem puniceus videtur, in iride non est color distinctus ab aliis, sed ex commixtione viridis et rubei visibus occurrit." However, the experiment of mixing red and green light from the spectrum would hardly be feasible in Witelo's time.

[76] Scaliger (*Exercitatio* 80 [299]) complains pettishly that this is making one eye out of all the eyes there are, and that two eyes cannot be at a single point. But Cardano is right to insist that the observer must be in line between the Sun and the centre of the rainbow.

[77] "Sic enim ex cava nebula perpendiculares radii reflectuntur"; "nebula" means a mist, a cloud of dust, a film or veneer; rainbows don't normally occur in a clear sky. A "concave mist" might allude to an impression given to the human eye that it is deeper in the direction of view than to either side.

reflected, it represents the appearance[78] of colours—for when light is made weak, it passes across into a bright colour, and if it is made still weaker, it changes into colours closer to dark. If this later goes even further, it reaches colours without light. In the end, it reaches dark when the light is minimal, and &283 finally as it fails, it passes across into gloom.[79]

So when rays get reflected to the centre from just the rounded and concave part, and if the film[80] is not concave, and there are more drops previously, the whole remaining film is indeed visible, but from a concave and rounded one the reflection becomes perpendicular, which represents the rainbow, that is, the Sun, just as when you see colours really varied and bright in water drops. Then when the Sun is on the horizon, and the eye, as I said, is in a straight line with the centre of the rainbow, the centre of the rainbow will have to be on the horizon, which is why the rainbow then appears precisely in the shape of a semicircle.The rest of the middle part has to be entirely below the horizon, if its centre is on it.

But when the Sun is situated higher up, it is obvious that a line drawn from the Sun's centre through the eye will lie below the horizon; so then the rainbow's centre will lie below the horizon. And the higher the Sun gets, the lower will be the line drawn from the Sun through the eye, and so too will the centre of the rainbow which lies on this line. And so the more the rainbow's centre is below the horizon, the greater the part of the upper semicircle that will be hidden from our eyes. Hence the higher the Sun, the smaller the portion of a single circle the rainbow has to be.[81] It is clear from this that the middle part of a rainbow is without mist,[82] and also that what lies hidden below the earth is not rainbow. For it is not from the centre of the mist that the rays are reflected, but the centre exists only in imagination. Also, it is certain that only one can be visible, for

[78] "species."

[79] Cardano's description of the generation of the colours is Aristotelian, and so is his emphasis on *reflection* here. Robert Grosseteste (ca. 1170–1253) in England inserted *refraction* into the account of the rainbow (see Bruce S. Eastwood, "Robert Grosseteste's Theory of the Rainbow," *Archives internationales d'histoire des sciences* 19 [1966]: 313–32), but did not explain the generation of colours by it. See also A.C. Crombie, *Robert Grosseteste and the Origins of Experimental Science, 1100–1700* (Oxford: Clarendon Press, 1953), 123–27, and he describes how Roger Bacon (ca. 1220–1292) too addressed the problem a little later.

[80] "nubes."

[81] Aristotle, *Meteorologica*, 3. 2, 371b27–30; Loeb 241: "The rainbow never forms a complete circle, nor a segment of a circle larger than a semicircle. At sunrise and sunset the circle is smallest and the segment largest; when the sun is higher the circle is larger, the segment smaller." However, the circle's size does not in fact vary.

[82] The word is "nebula," and rainbows do not occur in a clear sky free of water droplets, nor through refraction through very tiny droplets less than 0.05 mm in diameter, such as occur in a mist. (Minnaert, *Light and Color*, 197)

when the eye lies on a line which runs from the Sun to the centre of the mist,[83] no other rainbow could be visible except one with the same centre.[84] &284 But none could be with the same centre, since reflection from the Sun is impossible; the eye possesses the behaviour[85] of the centre of a concavity, not because there is a centre, but because from two points on the same line which runs from the centre, two lines to the same points cannot be reflected at equal angles. The remaining possibility is that from the first line another one is reflected, so that the second one has to be larger than the first, and much weaker. And so for a third to arise from the second is impossible. Then because a second one arises from the first one reflected, the lines or rays must lie inside the circle of the original rainbow, since they form a greater angle; they rebound further, the outer ones closer.[86] So the outer circle of the second rainbow will be blue, and the middle one green, as the outer one of the first rainbow is saffron—exactly the opposite of the original layout.[87]

I think it is obvious from this that when the Sun is on the meridian near the summer solstice, it has the maximum altitude of the semicircle. The result is that the rainbow's centre is below the visual horizon by the semidiameter of its whole circle,[88] so that the rainbow will not be visible. But it will be visible around the autumnal equinox, and throughout the winter, and after the spring equinox, but less so the closer it gets to the summer solstice and the meridian, as I said.[89]

Why is it then that when a rainbow is modest, and not much above the horizon, it appears as part of a larger circle? The reason is that the eye decides that the rainbow is further away, because it is lower down, since it understands distance as we said in relation to the stars. When it judges that the rainbow's top is further away, it also reckons that it is wider, as I &285 also said in connection with the Sun and Moon in the east. But the greater angle of the circle indicates that it is larger, and anyone can easily grasp this when he inscribes a lesser circle in a greater one in this way and they touch each other—it appears that the greater one is wider in the circumscribing line,[90] and for this reason a smaller portion of a rainbow looks like a part of a larger circle.[91]

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[83] "nebula."

[84] Mention of double or even treble rainbows comes later in this Book.

[85] "ratio"; behaviour as deduced.

[86] Nenci (369 n. 34) has traced this material to Witelo, *Peri Optikes*, 10, prop. 72.

[87] "ratio."

[88] The radius of the primary bow of a rainbow subtends about 42° at the eye.

[89] This correct statement is also substantially that of Aristotle (*Meteorologica*, 3. 5, 377a13–28; Loeb 279–81).

[90] Or circumference.

[91] It looks like a part of a larger circle, but is not so in fact; the angle between the axis of a primary rainbow (i.e. the line down the Sun's rays) and its arc is constantly 42°.

But rainbows do not originate only from mists, but also through reflection of light from drops of water from oars while they are being plied in the sea; and around lights in winter with a south wind blowing, especially by people who have damp eyes; and from sunlit drops scattered on a house wall and seen by an eye in shadow looking straight at them. As Aristotle rightly records, all of these have a single cause.[92] But Parelias,[93] Virgas,[94] and the Corona, which we saw around the sun and which people call a "halo," have the same reason for their colour that we

[92] Aristotle, *Meteorologica*, 3. 4, 374a21–b7; Loeb 257–59: "For a rainbow does form round lamps in the winter, especially when there is a south wind, and is most clearly visible to those whose eyes are watery, for their sight is weak and so easily reflected . . . The rainbow produced by oars breaking water is the outcome of the same relative positions as a rainbow in the sky . . . The reflection takes place from a number of minute waterdrops which form between them a continuous surface, and which are of course water already fully formed. A rainbow is also produced when someone sprinkles a fine spray into a room so placed that it faces the sun and is partly illuminated by it, partly in shadow. When anyone sprinkles water inside a room so placed, a rainbow appears, to anyone standing outside, at the point where the sun's rays stop and the shadow begins. It arises in the same way as the rainbow produced by the oars, is similar to it in colour, and due to the same cause, for the sprinkler uses his hand like an oar."

[93] "mock suns"; Aristotle (*Meteorologica*, 3. 2, 372a12–17; Loeb 243) wrote, "Mock suns and rods always appear beside the sun, and not either above or below it or opposite it; nor of course do they appear at night, but always in the neighbourhood of the sun and either when it is rising or setting, and mostly towards sunset. They rarely if ever occur when the sun is high, though this did happen once in the Bosporus, where two mock suns rose with the sun and continued all day until sunset." Seneca (*Quaestiones Naturales* 1. 11. 2) wrote that "the Greeks call them *parhelia*, either because they are commonly seen near the sun, that is, alongside it, or because they are near to some resemblance to the sun. They do not resemble the sun entirely, only in its size and shape. Moreover, dull and feeble, they have none of the sun's heat." They are concentrations of light at one or both sides of the Sun (though other variants exist), and can be accounted for by assuming that not raindrops but ice crystals are present in the atmosphere (Minnaert, *Light and Color*, 214–15; R. Greenler, *Halos and Glorias* [Cambridge: Cambridge University Press, 1980], chap. 2 *passim*).

[94] Virgae are streaks or stripes in the heavens, imperfect rainbows, and the obsolete term "water-gall" was once used in English for them. Seneca (*Quaestiones naturales,* 1. 9 and 10) wrote: ". . . mention should be made of Streaks (virgae), which, no less varicoloured than a rainbow, we commonly accept as equally a sign of rain. Not much effort need be spent on them, because Streaks are merely imperfect rainbows. They have the painted appearance of a rainbow, but have no curve; they lie in a straight line. Generally they form near the sun in a moist cloud that has already started to dissolve. Consequently there is in them the same colour as in a rainbow; only the shape is changed because the clouds also in which they are spread out have a different shape." These appear to be instances of the phenomenon named "circumzenithal arcs" by Minnaert (*Light and Color*, 218–19) and described as vividly coloured arcs parallel to the horizon.

mentioned. In fact the Parelias themselves happen only through reflection to the eye, no image at all being present in the clouds, and for that reason a cloud exists then out of droplets. So a rainbow and Parelias usually presage gentle showers, because the droplets consist of finely divided water, and the Sun's ray makes its way through. A Corona, however, has substance, being generated from reflection of the Sun or Moon or some other star, and resembling a rounded shape formed into a circle from the centre by a thick cloud. And so the eye does not contrive[95] these as it does a rainbow and Parelias, but sees what has been created and exists in the clouds.[96] It is as if you exposed a triangular crystal or prism or a hexagon[97] to the Sun—you will see on the opposite wall colours that are not imaginary, but real rainbow colours. Likewise, the same colours can be seen under a glass pot full of &286 water and exposed to the sun, or even to some clear light. But they will be imaginary if you look at crystal or at glass, because an associate will not see them at all the way they look to you, nor where you see them with the Sun present—he will see them looking different or in a different place, because they are not real, but proceed only from the way vision works.[98] [422]Hence I am astonished at people who say that where a rainbow has come to earth, it creates those famous perfumed plants, especially if they are already like that[99] by nature. Examples are laurel, juniper, myrtle; I think the reason is instead the one I mentioned, for the good smell of excellent earth after droughts when a shower starts.

Who has ever actually seen a rainbow leaning against a tree?—it exists only in the visual imagination, as I said. So what should be said, along with Aristotle, is that a rainbow makes its appearance with droplets; there is a low cloud, one that after long droughts appears over trees already perfumed by nature, and with a diffuse moistness of droplets instantly concocted, it evaporates marvellously into perfumed clouds.[100] This is what I have actually seen sometimes of a summer morning, in a rose tree already wilting; the scent from the dew to the near side of the rainbow was so fragrant that I would hardly dare to compare it to

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[95] "fingit."

[96] Aristotle (*Meteorologica*, 3. 2, 371b18–21; Loeb 241) does not draw any fundamental distinctions between these phenomena: "We must now deal with haloes, rainbows, mock suns and rods, explaining what they are and what are their causes; for the same causes account for all of them." Coronas are rainbow-coloured halos round the sun or artificial lights, and are discussed by Minnaert (*Light and Color*, 232–47).

[97] The precise meaning of the text here, "crystallum, trigonam, seu prisma, vel hexagonam" is not clear, but "crystallus" as a feminine noun is recorded from Pliny; the translation is a likely estimate.

[98] "ab oculi inspectus ratione."

[99] Perfumed, presumably.

[100] This is broadly the view of Pseudo-Aristotle (*Problemata*, 12. 3, 906a36-b34; Loeb 1: 297–301), who links the phenomenon to the presence of heated vegetation (and especially burnt wood) which is moist.

anything.[101] This is why those who have already seen a rainbow and are unaware of its nature ascribe the cause of the perfume to it. Morning[102] rainbows usually indicate showers, but evening ones fine weather with us, since our climate is generally like the sky at sunset, but there is sunshine in an evening rainbow. But a Corona and Virgas perhaps remain a long time undisturbed,[103] and presage clouds, for it is a thick cloud that stays &287 immobile so long without being abolished and dispersed by the Sun's rays. But if a portion persists, a portion is suddenly dispersed, or the whole is dispersed simultaneously, it presages winds, from the direction that directly overlooks the portion torn off, so that the wind is, so to speak, the bowstring of the Halo's bow left behind, or parallel to the uppermost part or the side of the torn off part of the Virga.[104] So if they wither gradually away, they provide evidence of the rarefied nature of the vapours, and hence of fine weather. Though both are horizontal[105] (the difference between a rainbow and a Corona is obvious, a Corona being a complete circle), Parelias and Virgas differ, because Virgas are oblong and marked out by rainbow colours, one, often two or more, and sometimes at the top of clouds, as it were over their head, sometimes as it were moving down, near the location of clouds — not very broad, but narrow, whence their name.[106] But Parelias, as it were rounded, or slightly oblong, display a twin Sun or Moon, and at times one from the individual sides of the Sun, with the effect that they reproduce three Suns, as I have once seen, and I did not sufficiently make out with my eye which was the real one, the rays originating from the sides were glittering so much. At the time there was a single rainbow, and a Corona as well, in mid-heaven (extraordinary to relate), though there was no Sun there, but all[107] were in the east. These occurrences only go with a Sun in the west or the east, while a hollow thick cloud[108] picks up and returns the rays. When therefore there have been three Moons, the middle one will be the true one. A twin Moon is a rare event, and a triple one &288 very rare — it would only happen, as I said, with the Moon in the east or the west, for the reason provided in connection with the Moon; and almost always at full Moon, since the Moon is weaker at any other time; pure air and a very thick cloud are

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101 I have translated the "quicquam" of 1550 and 1554, not the "quanquam" which crept into 1560.

102 This sentence first appears in 1560.

103 "inconcusse."

104 "ut sit quasi ventus chorda relicti arcus Halonis, vel equidistans parti supremae, aut lateri avulsae partis Virgae."

105 "rectae" —a parhelion is a false Sun beside the real one, so can hardly be "straight"; but virgae (streaks) can be; see the quotation from Seneca above.

106 "Virga" means a stick or rod.

107 The various appearances, presumably.

108 This phrase "cava nubes" is quoted by *OLD* from Lucretius, Ovid, Vergil, Statius, but the "poetic fancy" (*OLD*) involved is not evident.

required. When it is going to be triple, obviously two such clouds should be present, established at suitable places. A double Parelia of the Sun is commoner than a single[109] one of the Moon. A single one of the Sun is common, but hardly seen by any sailor, and then accompanied by great danger.[110] An extra contribution to the scarcity of Parelias of the Moon is that people are not watchful enough in the night, and they[111] remain in unclouded[112] locations and under the open sky, as they do by day, so that far more perhaps occur which are not observed. In the case of the Sun's image[113] it is impossible for them all to pass unseen, with so many people being out of doors. And, as I believe, the reason why few rainbows of the Moon are seen is the same—they are visible primarily by night, when the Moon is anyhow almost full of lights, not much this side of the equinoctial circle and close to the horizon. It is reported that one was seen twice in one season in Germany, where one is seen more often because of the altitude of the pole and the thickness of the clouds. It is much whiter than the Sun's rainbow, so that a dim greenness is mostly presented instead of blue, saffron instead of green, and white instead of saffron. It is evident from this line of thought that since the Sun or the Moon are never pushed to the north behind our heads, and the rainbow's centre is on a line from the Sun to the eye, a rainbow can only be seen in the east, the west, and the north—never in the south, except so far as it may happen, from the &289 diversity of the Sun and the horizon, that in summer walls may be illuminated by its first rays at dawn towards the north. When the Sun actually rises in summer, where the tropic of Cancer[114] intersects the horizon, spherical calculation[115] tells us that when we look toward the south, it stretches out shadows so oblique that they seem to be making for the south. The same principle is in full bloom[116] when it sets—since the top axis descends towards the Earth's centre, and the Sun is moved towards the Earth's centre in the tropic of Cancer, the closer the sun is to the horizon, the more to the north it must appear to us, since in comparison with the lowest part of the line that leads to our vertex, it

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[109] "simplex."

[110] Meaning is uncertain; the Latin runs: "simplex autem Solis frequens est, ac nullis nautis penè, magno etiam cum periculo, non visa."

[111] The Parelias, presumably.

[112] "apertis."

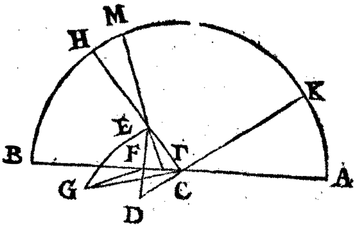
[113] Freely translating "Solis imagine" by "In the case of the Sun's image."

[114] The tropic of Cancer is north of the Equator, and in this passage Cardano is correct; but see n. in Book II at 220 (1560) above for passages where he substitutes "Capricorn" for "Cancer."

[115] It might be anachronistic to translate "ratio sphaerae" as "spherical trigonometry."

[116] "viget."

really is northerly.[117] The "sagitta"[118] reaching the tropic of Cancer on the surface of the horizon is too short to reach us.



From these features let us learn how to measure how far the rainbow we see is from our own feet.[119] Let there be an arc AB of a semicircle passing through the Sun and our eyes, and our top[120] and the centre of a rainbow, and then its top AB. And let the centre of the universe be C, the centre of the rainbow D, and its &290 semidiameter and "sinus versus seu sagitta"[121] EF, the lowest middle of the rainbow arch as it appears is EG, the Sun K—then because the arc KA is known, there will be also an angle at C, as if the point C were the universe's centre, an angle known because of its [423]distance. Hence the angle DCF and F is a right angle; therefore the triangle CFD is known from the table of chord and arc. We will then draw[122] GEH, and the arc BH will be known at once from the planisphere. This is in fact the primary application[123] of this instrument, and a very easy one, which occurs to us immediately. So the angle BCH is known, and in the same way CFE is a right angle.[124] So are the triangle CFE and the ratio of the five lines CD, CE, CF, DF, EF, and the length of a part of the semicircle EG extracted from the table of chord and arc. For having determined[125] DE as 60, you will double FG, which I will explain below, and it is the arc for that chord straight from the written

[117] Here Cardano can be understood; on the assumption that he is at Milan or in that neighbourhood, the midday sun does lie relatively higher up in summer, over the Tropic of Cancer, but south of the latitude of Milan. The previous sentence remains unclear.

[118] "Sagitta" here might mean "an arrow flight," but it is also a technical term of spherical geometry, meaning "the part of the perpendicular bisector of the chord that is cut off between the chord and the arc of the circle" (Kepler, *Harmony of the World*, trans. Aiton et al., 58 n. 192). This seems much more plausible. This sentence first appears in 1560.

[119] Witelo's *Peri Optikes* X. 77 entitled "Datae iridis semidiametrum invenire" is cited here by Nenci, 376 n. 45. This proposition opens by referring to the height of the limit of the vapours as the topic of proposition 58, but Witelo evidently is referring to his proposition 60. I cannot follow Cardano's figure and argument here. On Witelo see n. 56 and n. in Book III at 253 end (1560), in which proposition X. 60 also appears.

[120] I.e. the top of our head.

[121] On "sagitta" see n. 118 above; "sinus versus" is evidently an alternative term for the same item. In modern terminology, versed sin(x) = 1 — cos(x), because we now conventionally take the radius to be 1. I am indebted to Dr Jackie Stedall for this observation.

[122] "ducemus."

[123] "operatio."

[124] "rectus."

[125] "posita."

record.[126] The arc of the whole seen rainbow is double GE. And so you now have the quantity of a rainbow, though unable to see its bottom, that is, the point G; you can actually hardly ever be sure whether the point G is the bottom of the rainbow, because of the unevenness of the places.[127]

I move on afterwards to L, and see the altitude BM via the point F—so the angle MEH is known, because, as has been made clear, the vapours do not ascend very much, but the mist much less—as Albertus Magnus thinks, not more than 15 stades.[128] So it is as if the angle HCM were at the earth's centre, and so CEL is known, and LCE was known, so CLF, and the whole triangle CEL via the same table. And because the angle FEC was known, and LEC, the angle FEL will be known, hence as F is a right angle, the triangle FCL will be known. Hence the proportion of FL to LE is &291known, and now that of LE to LC is known from the triangle ELC, so the ratio of FL to LC is known. But LC is a known measure—it is actually the distance you have moved on.[129] So FL is known, and also FC from these same components. FG is known, because EF is known and ED. Hence when you draw EF as a composite from ED and DF, and have found the square of the side of the product, you will have GF out of the 8th in Book 6 and the 31st in Book 3 of Euclid's *Elements.*

So with CF drawn into itself, and FG into itself, the side of the composite,[130] the line CG is the distance from the location of the rainbow, where it touches the earth. It is evident that if anyone goes up onto a very high mountain, the rainbow will be seen as larger than a semicircle, and the more so the higher the mountain. The interval it occupies in front of the eyes has its basis in a vacuum.[131] And we should be aware that the biggest rainbow in our regions does not rise more than 42 degrees above the horizon. A rainbow would be largest when the Sun is at its rise or setting, and the line CF has been at its longest. So it is agreed too that one can find out what the greatest distance of a rainbow from us may be, by supplying its size—then its magnitude is already known from the actual distance, as has been described, by comparing the line FG to the line CG already known.[132] It is now established from reflection[133] that if a mirror is placed under water, the Sun's image will be reflected from the water and will reproduce the Sun, but another

[126] The table of chord and arc, of which the later equivalent is the table of sines.

[127] "locorum inaequalitatem."

[128] A n. in Book II at 94 (1560) runs: "In classical times this corresponded to 740 metres (*OLD*). So 15 amount to 11.1 km or nearly 7 miles."

[129] "processus."

[130] "latus aggregati."

[131] "vacui habet rationem." Cardano's language is surprising since Book I devotes much attention to the vacuum, and holds that it "does not occur" (55 [1560]) but that numerous effects ensue from its avoidance.

[132] The argument appears extraordinarily circular!

[133] "ex reflexione."

image, narrowed down from the water's surface on account of the medium's compactness, will be reflected by the mirror, and is reminiscent of the image of a small star, and people think it is some star &292 close to the Sun, one revealed by this manoeuvre, since it is sufficiently agreed that the image is of the Sun, but refracted by the water into the mirror—an image which people generally keep seeing in a mirror at Solar eclipses, while they are eager to view the eclipse.

But when the Sun undergoes eclipse, why does its image transmitted through an angular opening reproduce the shape of a ship? I now have to explain the remarkable arrangement[134] of the rays, but gradually—it is difficult. For I must show why, when they first traverse an angular slit, they display on the plane before them[135] a rounded shape, not a straight one, and the more rounded the further the plane is from the slit. The reason for this is twofold, and has been gone through above:[136] the lines that were coming together previously, the further they go, the more they approach the nature of parallels. The outcome is that as they depart from the nature of angles, they approach more to a round nature. This then is what we have already shown in a previous figure, and the more so, because the rays proceed from the whole of the Sun, not from one point. The second reason is that the more the shape departs, the more the image is increased;[137] the eye abandons the part of the object which is weaker than the minimum visible, as we assumed from the start. Since the rounder and large part shadows the angles with its illumination, the parts of slenderer powers—that is, the angular parts—have to stop moving vision along earlier in the media into which a plentiful ray is being emitted. So these rounded figures will make an appearance, and the more rounded the further they are &293 not only from the slit through which the rays pass, establishing it,[138] but also from the eyes of the onlookers. So since these points are very clear, and where illumination is received under its own quantity, so to speak, if anything should be in between, it will be carried off with the shadow. So with the Sun's image being at reduced magnitude, so to speak, where it is supplied to the eyes courtesy of the slit, since the Moon is interposed (a dense opaque body), the Moon's shadow must appear too in the shape. But the Moon's shadow is rounded, and the form from which it is excised is rounded; so when a rounded item is removed from a rounded item at one part, what can be left is the image of a little ship or an empty Moon, and what has to happen in eclipses is that the forms drawn on planes by rays traversing angular slits are neither angular nor rounded, but moon-shaped, or shaped like a little ship. But

[134] "ratio."

[135] "subiectum."

[136] This is presumably the account in this Book on 272 (1560) of why a round object seen through a square grating still looks round.

[137] This is a guess: the text runs: "Altera est, quòd cùm figura, quò magis abscedit, eò magis augetur. . ." and its syntax is problematical.

[138] "illam constituentes"; the meaning is not clear.

careful inspection is needed, since when the Moon is porous,[139] a figure of that same kind will appear as round.[140] But the brighter portion, as I said, reproduces the lunar shape.

I wanted to add these details, because I did not want to write anything false or uncertain in this book, as I said in the preliminaries.[141] And if there is anyone for whom my proposal does not prosper, he will himself stand self-accused of ignorance, not I of lying. But I return to the point. At the time of the same eclipse, everything looks [424]saffron-coloured, and considerable headache befalls many people too. The reason is that illumination is scanty, and saffron-coloured for that reason. Dawn shows this, being herself saffron-coloured—hence Vergil's line:

> &294 Dawn departing from the saffron-coloured bedchamber of Tithonus.[142]

In fact, on the evidence of Servius[143] relayed from Varro's[144] authority, the ancients used to start the day from dawn, and divided it into four parts. Of these, the first was morning[145] (known also as dawn), a word derived from "manus" which means "good";[146] this was the way in which the ancients used to greet each other while getting up in good time. Next was daybreak,[147] from sunrise up till the fourth hour, a name they chose because the Sun appeared to be moving upward all the time. Midday was from the fourth to the eighth hour, as if the Sun were taking a midday rest.[148] And up to the twelfth hour was sunset, because the Sun

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139 "pervia"—perhaps this refers to the fact that the part of the Moon not illuminated by the Sun can show up rather dimly, through indirect illumination from Earth.

140 The meaning is unclear here.

141 "praefatus sum"; there is a Dedication but not nominally a Preface.

142 *Georgics* 1. 447. Tithonus was the mortal husband of the dawn goddess Aurora (Ἕως) and very unlucky—being very fond of him, his spouse begged Zeus to grant him immortality, but omitted to ask for perpetual youth. Tithonus aged lamentably, and talked interminably, and she locked him up in the bedchamber. The pathetic tale is in the *Homeric Hymn to Venus*, 218 ff., and variants exist (see the *Oxford Classical Dictionary* under "Eos," and Brumble, *Myths*, 325).

143 A commentator on Vergil in the fourth century A.D. These two paragraphs first appear in 1560.

144 Marcus Terentius Varro (116–27 B.C.), prolific philologist and librarian, the "greatest scholar among the Romans" (*OCD*), though his derivations of Latin words now often appear fanciful.

145 "mane."

146 A Latin word "manus" meaning "good" is in fact attested by such a scholar as Festus, in the 2nd century A.D. And Varro did indeed offer the same information.

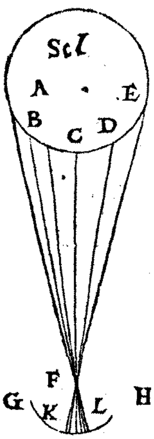
147 "ortus."

148 "meridiaret"; "meridio" means "to take a siesta," and one may guess that this is the allusion in the present context.

was descending and ended by being concealed. Then these hours were equal: that is, twelve being the part of the day from the Sun's rise to its setting.

Night was divided into five: "evening," also known as the nocturnal twilight or uncertain light; the "quiet of night"[149] when the air was darkened—during this they devoted themselves to quiet; the "dead of night,"[150] which exceeded the limits of watchers and was of no use to those who got up, and was the period from four to eight hours; then "cockcrow" till nearly ten; from then till dawn, "morning star."

But to return to my plan: on the same basis there has to be a major change in the air at the time of an eclipse, because of which those whose heads are weak get headache. But you will say, "Surely when the Sun rises, too little illumination reaches us, and when it sets too, yet the illumination is bright, like what enters a dark chamber by a small orifice through a window?" But the reason for this is that when the Sun rises or sets, it takes very little time, but it stays in eclipse for a long time. But anyone who examines the first rays of dawn or the last of sunset at the time from far away, rays which do not come from the centre, will see them as saffron-coloured, without doubt. &295 Two things are obvious from this: the Sun gives forth rays from all of it, not from its centre alone; yet the rays given forth from the centre are more powerful. Even if you cannot accept this, at least you can start by agreeing that it does no damage to the points being proved. But as I said, it is plain that rays emerge from the whole of the Sun, as they do from a fire, from all directions, because at the time of an eclipse the part opposite the centre is taken up by the Moon, and yet the air and walls are illuminated.



There is a feature[151] of the concave mirror that displays this, since all the rays would not be able to come together in one point in any other way, unless they were proceeding from the whole Sun. Contrive that a mirror is illuminated only from the centre of the Sun—unquestionably only one ray will return into the centre of the mirror. How then does it come about that fire is always ignited in the centre of a concave mirror, and all rays from the Sun come together?—Euclid in fact proved this correctly in his work on mirrors. For from ABCDE all the rays between K and L are reflected into the centre F, not just from one circle, hence fire is ignited at F.[152]

But you will reasonably feel doubts: firstly, why do the rays that are reflected into themselves (the only ones that are perpendicular) come to be strong? The reason is obvious: what is reflected

[149] "conticinium."

[150] "intempesta"—"intempesta nox" is a Ciceronian phrase for the dead of night.

[151] "ratio."

[152] The figure here is in error; the rays from the Sun should run parallel until reflection occurs, and then become concentrated.

away from the perpendicular returns into itself, as happens &296 from E to F, from K; consequently the whole ray is duplicated in relation to its length. But one that is reflected from another point into EK cuts and departs; but one that cuts does so at a point, so contributing no power. Since a point in fact has no quantity, it lacks powers too, even if unlimited rays are reflected through the same point, they are none the stronger. What is actually nothing gives rise to nothing, however much you double it. Therefore there is absolutely no cutting power[153] in rays that are not reflected from the perpendicular. But in close ones and closer ones, there is correspondingly more power, since one ray is close to another, not because it cuts at a point, for cutting is of no importance, since, as I said, it goes on in an indivisible thing, but nearness matters; if a ray sticks to another in relation to its length for a long time and over a wide interval, the power of each combines and is as it were doubled. It is as if I said, "Since[154] it returns alone from the perpendicular into itself, even on its own it doubles its power precisely."

The second doubt was: if there is a large mirror from the direction KG, why do the reflected rays not illuminate the neighbouring parts around F, so that at least clarity is restored, but all these rays are reflected below F? For if a ray is drawn from E to G, the angle EGK will be larger in the right angle FGE, so it is reflected below FG through the angle FGE; hence the bigger the mirror is, and the larger the portion of its sphere, the more and the faster it ignites things. Yet a mirror of this sort cannot ignite fire at a distance, since the rays are always concentrated in the centre.[155]

There is a third doubt, no trivial one. The rays that are reflected &297 out of the part EC from the point K, so that a ray proceeding out of K from the point D is reflected towards H, and will at any rate illuminate the parts adjoining F—this is contrary to experience. It is clear that this is more so in the rays that are extended from B and C into K. The reason for this is that they are scattered, and there is no perpendicular ray, and the huge illumination in F obscures the nearby parts. Also, a ray reflected from a concave mirror is weaker than one from a plane one, which goes astray if it is not perpendicular. So the causes of the strength of rays are: in themselves, combination from the perpendicular,[156] as happens in concave mirrors; next to that is reflection from the perpendicular without combination,[157] as in plane mirrors exposed directly to the Sun. The third cause following on is reflection not from the perpendicular, yet [425]still to equal

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153 "nulla prorsus est vis, ut secent."

154 "Quasi dixi, quoniam solus à perpendiculo cùm in se redeat etiam solus vim suam exquisitè duplicat"—the syntax is odd, since "quoniam" and "cùm" are both present here to do one job, unless perhaps "cùm" can be interpreted here as "although."

155 I cannot interpret this paragraph confidently in the light of the figure just above, especially since the Sun's rays are effectively parallel.

156 "coitio à perpendiculari."

157 "coitione."

angles, as by a plane mirror not directly exposed to the Sun—the eye does not support this either. The fourth cause does produce an image, but one that can be supported, when the rays are reflected to an equal angle, but scattered, as occurs in concave mirrors outside each pyramid, and it is an image which passes from the centre of the mirror to the mirror, and from the centre of the mirror to the thing seen—as happens outside the pyramid FKL and FAC. The fifth cause is when the rays are reflected from a body which is not polished, and are useless for vision, though not for heat; these perpendicular reflected rays, as I said, redouble the heat on account of combination,[158] but do not produce an image. The causes of the strength[159] of rays are listed in terms of "accident":[160] size and nearness of the light source,[161] and that the ray in question emanates from its centre; then the purity of the medium and of the rays themselves. Through these causes it happens that one illumination may turn out stronger &298 than another—hence we can stand the reflection of the Sun's rays from the Moon and stars, because of the distance, although it is quite a pure[162] reflection, but our eyes cannot stand it from crystal and water.

In fact two methods appear to exist[163] for kindling fire from a mirror: the first, that all the rays falling on the mirror's centre are assembled in one point by reflection, which occurs, as was said, with a spherical concave mirror. The second is for all the parallel rays emanating from the Sun to be assembled in one point, which actually[164] happens with a parabola.[165] I find in Conrad Gesner[166] that Francisco Maurolyco of Messana[167] wrote that books by Archimedes survive on this matter, where he shows that burning mirrors are made by a parabola. That

158 "coitio."

159 "robur."

160 The philosophical term.

161 "lucidi."

162 "puriorem."

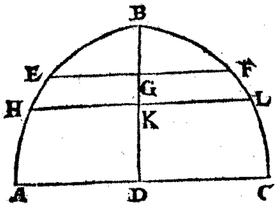
163 The text runs "Verùm cum duo videantur esse modi . . ." but I have ignored the "cum," since Cardano seems to have shifted the syntax in mid-period, and it remains elastic to the period's end.

164 "etiam"—the meaning "also" does not seem to fit the facts here.

165 More precisely, a paraboloid, the three-dimensional result of rotating a two-dimensional parabola round its axis. A mirror of this shape brings parallel rays entering it to a single focus.

166 Conrad Gesner (1516–1565) was a Swiss naturalist and physician, notable for his well-organised assembling of information on animals and plants. He was also appointed a professor of Greek at the age of 21. For further details see *DSB* 5: 378–79.

167 Mess*i*na, not Messana. Maurolico (1494–1575) spent virtually all his life in Sicily, and wrote extensively as a mathematician with wide scientific interests; he produced a collection of the works of Archimedes, but it was not published until 1685, and he did notable work on optics. In his *Theoremata de Lumine et Umbra ad Perspectivam* (finished in 1521), he explains how to build a microscope, and observes that in a pinhole camera,



is the actual situation. When a surface intersects a right cone[168] and a diameter[169] of the surface is parallel to the side of a triangle inscribed on the surface and intersecting the cone along its axis from the vertex, that surface is called a parabola, which is to be ABC, and a straight line &299 from the vertex of it B and dividing the straight line AC lying below with equal sides, the curves BA and BC,[170] let the diameter be called BD. And the diameter[171] is AC, the base of the cone is K,[172] the middle is BD; I say that HKL always has such a ratio to any perpendicular coming from the side above the diameter as the ratio of the perpendicular itself to the part of the diameter intercepted between the vertex and the perpendicular.[173] For example, let the perpendicular be FG—then HL will have a ratio to GF such as GF has to GB.[174] And then HL will be called the "latus rectum,"[175] and all the parallel lines or rays BD can be reflected into K. In fact HL is always four times BK.[176] But if the intention is to make a mirror which will burn at a distance, like the one Galen[177] says Archimedes made, which burnt up the enemy's triremes, it is clear that mirrors, whether derived from the parabola or from the circle and sphere, need to be huge, that is, portions of huge spheres or cones, but not a very large part of a parabola. If, for instance, one wishes to extend fire to a mile away, we will mark out a circle, whose diameter is to be two miles, and let us take a part of it big enough for the roundedness to be evident, that is to say, a sixtieth part; let us add to it at one end a diameter in relation to height, and with the diameter

an object's shadow moves in the opposite direction from the object, and he observes solar eclipses with a camera obscura. For further details see *DSB* 9: 190–94.

[168] A technical term meaning a cone with its apex angle a right angle,

[169] A diameter ("dimetiens") of a parabola, properly speaking, is a line parallel to its axis—i.e. it only intersects the parabola at one point.

[170] Confusing, but the diagram helps; note that G is at the midpoint of EF.

[171] See n. 169 just above.

[172] It is apparently the *focus*.

[173] The following three sentences appear first in the 1554 edition, replacing material of which the text appears in Nenci, 421 as Appendix 2.

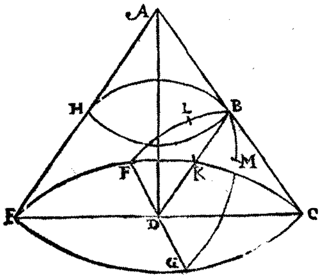
[174] Suppose the parabola is $y^2 = 4a(x-a)$, which will turn the diagram 90° to the left. Then $BK = a$ and $HL = 4a$. Let $GB = \alpha$. Then $GF = 2\sqrt{a\alpha}$. Hence $HL/GF = 4a/2\sqrt{a\alpha}$ and $GF/GB = 2\sqrt{a\alpha}/\alpha$ which are equal.

[175] As it still is.

[176] While this is confusing, it appears to enshrine the well-known fact that rays entering a paraboloid mirror parallel to its axis are all reflected so as to pass through the focus; and the length of a chord of a paraboloid passing through the focus at right angles to the axis, called the "latus rectum," is indeed four times the distance from the vertex to the focus.

[177] In his *De Temperamentis*, 3. 2; K. 1. 657.

fixed, let us draw round it a part of a circle, which will mark out for us a portion of a sphere. When we have got it polished, when it is exposed to the Sun it will ignite powerfully from a distance of a &301 mile. Nowadays this is not so useful, because of military devices,[178] but it was once a great security.[179] The conflagration that proceeds from a parabola is more powerful.[180] It comes about like this: let the place requiring to be incinerated be a mile away. I make BK a mile



long and add to it a straight equal line KD, and to this BD I make BA equal at a right angle, and from the other side BC equal to BA, and having drawn DA and DC, I make D the centre of the base of a cone, and AD the axis, since the angle ADC is a right angle, and I rotate AC to generate a cone, and let a circle be drawn from the line DC as a semidiameter through the cone's base; I divide this by two diameters intersecting each other at right angles, CE and FG with the centre D. It will actually be the case that the point B draws around the cone the circumference of a circle that is HB. So I draw from the vertex of the cone a straight line to the end of one diameter of the base, say at C, and where it cuts the circumference of the circle, as at B, from that point I draw straight lines BF and BG to the ends of another diameter. So the surface in which the triangle BFG lies, where it cuts the cone's surface, forms two oblique lines BF and BG, which need to be made of best steel to prevent their bending. Using only a part, suppose that BL and BM are equal, which are sides of a parabola.

Then you will take up a mass N[181] of gypsum, greater than the [426]width LBM in the vertex, and rub it gradually with whetstones till the parabola LBM placed on it and rotated round it touches it on all sides and can rotate without obstruction. When you have finished this, apply red-hot[182] glass to this mass, and

[178] No doubt artillery is meant—compare Jean Fernel's enthusiasm on this score: "The advance of time has not only contributed lustre and additions to what has already been discovered; it has brought forth in addition new arts, to which neither the talent nor the diligence of our predecessors had ever attained. Antiquity admired Demetrius, naming him 'the besieger' because of his invention of a military contrivance; how much more distinction we should award to the inventors of devices in the present epoch, which have been called 'bombards' after their burning bomb, so to speak. Ye gods, how much more violent is their flight than a ballista's, how much faster than a catapult's or a tormentum's?" See Forrester and Henry, *Jean Fernel's On the Hidden Causes of Things*, 107–9.

[179] "tutissima."

[180] The remainder of this paragraph together with the next one first appear in 1554.

[181] It is thus marked in a separate part of the figure, not shown here.

[182] "candens."

you will complete a parabola which with lead[183] &302 sprinkled on from the rear will reflect[184] all the parallel rays from the Sun, the strongest ones of all, onto the point K, a mile away, and burn it up on the spot. This was plainly demonstrated by Archimedes, as in fact Antonius Gogava[185] passed it on to us.

But after I set about recounting the prodigies in connection with mirrors, I planned to explain the makeup of a mirror in which we can see hidden things.[186] Join together in precise equality two manufactured plane mirrors of crystal, the sort made in Venice, because they are not contaminated like steel ones—join them in such a way that the length of one attaches exactly to the length of the other, and so that it can be rotated round an axis like a wrapping, in such a way that the surface of one sometimes makes one plane together with the other's surface—sometimes a solid,[187] a right angle,[188] an obtuse or acute one, according to choice. Then you will suspend aloft the fixed mirror from the direction of a concealed place, in such a way that the mirror's face is poised perpendicular to your plane. Let the moveable face of the mirror have its length opposite to the place you require—then whatever goes on[189] in that room, provided some light gets in, with the moveable mirror being rotated until it makes the angle equal (a position your eye will assess), you will observe everything while you look at what interests you.[190] But if the place you need to see is higher than the one where you are, hang the device from a higher point.

On the same basis, if you want to see something five miles away, and with walls intervening, or in a hostile township, hang a mirror on a high spot, vertical or so far as possible &303 parallel to the horizon,[191] with another mirror in your hand, arranged so that its face (neither face upward, nor precisely set vertical) looks at the mirror you placed above. Finally, you will extend yourself little by little in line with the first mirror, and gradually bracketing,[192] bending now right and now left till you see the place fully in your mirror, then barely moving it from its position, you will see whatever is going on and happening there, and although

[183] See n. 26 on p. 226 above.

[184] Translating "reflectet . . . comburétque" though the text reads "reflectent . . . comburéntque."

[185] This scholar of Oriental languages was first to translate Ptolemy's *Tetrabiblos* into Latin (*Cl. Ptolemaei operis quadripartiti in Latinum sermonem traductio; item de sectione conica orthogone, quae parabula dicitur; deque speculo ustorio, libelli duo*, published at Louvain in 1548; Maclean, *De Libris Propriis*, 200 n. 95).

[186] "occulta."

[187] I think that must be when the two flaps are closed together.

[188] Between the two flaps.

[189] "geretur."

[190] "quod quaeris."

[191] This must be a periscope, but the description is hard to follow.

[192] "paulatimque ac alternatim."

as I said,[193] there is no other obstacle to this thing but that of fiery devices, it can still be of use to a few people, since a sizeable thing displayed in such a small mirror can only be detected by the sharpest vision.

But if you would like to view what is going on in the street, when the Sun is shining you will put a glass ball in your window, and then when you close the window, you will see images transferred through the gap onto the opposite flat surface, but with dim colours. So you will lay a piece of very white paper on the place where you see the images, and follow the serious business on a remarkable basis. Double faces, sets of four eyes and three eyes, and yourself with one eye, and your likeness turned away, and other countless marvels will be revealed by a concave mirror—not only a spherical one, but also a conical and a cylindrical one. However, this last will make things look much larger, such as sets of four faces, and an oblong and a very narrow face, and sometimes a very short and very broad one. What then?—almost everything except the true face, after the fashion of to-day's people, who know everything except how to do good or tell the truth.

&304 And mirrors exist that show many faces, as they consist of many planes.[194] But the best known is the one deserving admiration, which with a single surface presents many images. I used to have a square plane mirror made of glass, which reproduced each ear as twinned, as if there were a second image of the first one, and it was further off. This made me believe that there had been a mirror in Spain—a plane one, too—which reproduced a double image of a face: the one, the nearer one, very true to life, the other like a corpse's image; in fact the arrangement[195] was the same in both. Let us explain the reason for this, so that we understand the feat and can explain how to bring it about; those who actually see such things are in terror, not only from the marvel but also from the image itself. In fact the back[196] of the ears used to look quite pale. So since these figures are paler and less effective and conspicuous, and like the primary images, it is clear that as in the case of the double rainbow, the later one originates from the earlier one. But where is the reflection from? It does seem that there is not always a double rainbow, nor are there double images except in a few mirrors. Then let the eye be A, what is seen be B, the mirror be C, a convergence[197] to equal angles at the point C, a convergence with a straight line from B to the perpendicular above the mirror at D, where B will also be seen. Then when A and B are sharply &305 inclined, because ACB is not far from the mirror's surface, the image is refracted from C, because the mirror is not exactly plane, into E. Then E is higher than C, so F will be seen above D. As it appears higher and under

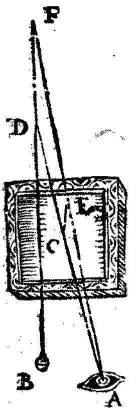
[193] Reference not traced. The remainder of this sentence first appears in 1560.

[194] The following twelve sentences first appear in 1554.

[195] "ratio."

[196] "posteriores."

[197] "concursus."



an equal angle, it is regarded as even longer. Hence F is seen behind B as well.[198] And Scaliger[199] says that if very clear glass is spread over a shiny mirror of steel, a twin reflection can arise from the same opacity, and so also a twin image, as we saw in connection with double shadow. But surface must be separated from surface, and tilted.

There are other devices that kindle fire, because they consist of numerous circles, and in short, unlimited monstrosities of complexity,[200] superfluous to mention. Now let us demonstrate the ones that reproduce images in the air. We described concave ones above; there are also convex spherical ones, [427]and very sophisticated[201] cylindrical convex ones. Let a slit in a window be set in line with some painted picture, in such a way that it can be viewed through the slit from any place in the room. In that place let a cylindrical convex mirror be set up on a tripod perpendicular to a plane, and next, position your eye so that you can see from the mirror the picture you placed outside—then you will see the image as hanging in the air between the mirror and the slit in the window.

About[202] the shape: concave reflectors show larger images, rounded ones much smaller ones, plane ones that are somewhat &306 equal but are large in relation to size and position show larger ones, and so roughly[203] do small ones a long way off. So rounded ones are roughly like small plane ones, since the reflection develops from a small portion in them. Also, the conjunction of rays with the reflection which is making for the centre is nearer, hence its base is smaller. Consequently they enlarge at a distance, even beyond the size of the thing seen. Likewise too because of the thing lying oblique in relation to the mirror, as my father noted in the second book of his *Optics*.[204]

But if anyone wants to see people in flight in a mirror, there are four requirements so that they appear to fly. These are to move, and to wave their arms—the

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198 I have not succeeded in interpreting what is described here.

199 Scaliger, *Exercitatio* 82(3), 316–17, describes in some detail the creation of a mirror embodying four types: plane, concave, convex ("curuam"), and cylindrical ("columnarem"). It seems to produce a series of images, one upon another, and the glass is spread not on steel but on an alloy of tin, brass, and arsenic. These two sentences first appear in 1560.

200 "compositorum."

201 "exquisitissima."

202 This paragraph first appears in 1560.

203 "prope."

204 Nenci (392–93 n. 68) notes that Cardano's father arranged the first edition of the Englishman Johannes Pecham's *Perspectiva communis*, without contributing anything extra himself, but Cardano might have found a manuscript addition by his father.

person you want to see flying will provide these two, whether it is yourself or other people. Although you can fake the movement by moving the mirror, that is highly inconvenient. The third requirement is for the mirror to be suspended aloft, to prevent it looking stuck to earth. The fourth is this, that as is the case with birds in flight, the legs, head, and arms should be parallel to the pavement. A mirror will provide these two very prettily. So get two equal pieces of timber joined at a right angle, so that the right angle is at the top, and unite light[205] pieces like a gnomon.[206] Set up two large plane mirrors inside beside the angle, facing each other and at an equal height—you can grasp clearly enough that they are pendulums. So when you move back from this far enough to make one of your heels follow the other exactly,[207] then by moving along a straight line and shaking your arms, you will seem to be looking at a person &307 flying.

On the same bases that we have mentioned: if you place two mirrors touching each other and on one plane surface, in such a way that when one moves towards you, the other moves away, which will happen if they have been placed on a beam in line[208] and perpendicular, and the link[209] which is concealed is gradually revealed, you will see your image advancing in one, and retreating in the other. And if you want to see your back, you can achieve this conveniently with two plane mirrors, and the bigger the ones you got, the better the actual result. You will position the first behind, at the mid angle[210] between facing upward and vertical, and the other at a higher level than yourself, at the mid angle between facing down and vertical, in front of your eyes—and you will be able to get an excellent view of whatever you have on your back.[211]

Bear in mind too that if, for instance, you have put a ring facing the mirror, the ring itself becomes a mirror, as if with a sapphire[212] enclosed in it, and you will see in the mirror an image of the ring; in its gemstone your own image will be seen, which will occur through multiple reflection. The same will occur in two mirrors, and with much more remarkable effect in three.

But if you plan to see dim and deep-down things, such as the womb, the throat, or a dark room, place a large glass vessel full of water in line with the place,[213] and illumination behind the vessel, so that the vessel is on a straight line between the illumination and the place you seek to see. Then remove all other

[205] The word translated "light" is "levia."

[206] The part of a sundial that casts the shadow.

[207] "ut in altero calcaneum ad unguem assequaris."

[208] "rectè."

[209] "vinculum."

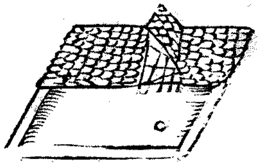
[210] "situ."

[211] It is very difficult to follow what Cardano means by this and the preceding mirror illusion he mentions.

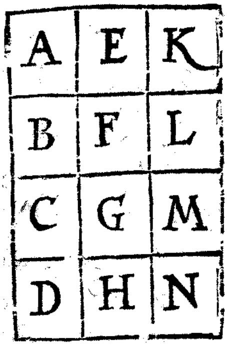
[212] See n. 268 below.

[213] "è directo loci."

illumination, and put your eye where you are not in the way of the vessel's &308 illumination but can still view the place—and you will see everything as in clear light. But if you wish[214] to illuminate places under a house roof securely, and you are unable to obtain the illumination from the side walls, set up an aperture[215] in the roof from the direction in which your eye is looking, and cover the place with a grid, and make the roof slope right to the middle of the cover of the aperture; in this way neither thief nor rainwater can get in.[216]



There are people who have contrived mirrors displaying as many faces as there are hours in the day—Ptolemy testifies to this. But in addition, a part of the image used to indicate the part of each hour. Let there be a right-angled quadrilateral, one third longer than wide, divided into twelve equal squares ABCDEFGHKLM and N.



Let a mirror be set up on the same plan, divided into the same number of intervals, and above it a covering higher at A than at B, &309 at B than at C, and at C than at D, in such a way that D touches the mirror. Let there be the same proportion[217] of E to F, and K to L, as there is of A to B; and F to G, and L to M, as there is of B to C; and G to H, and M to N, as there is of C to D. Let the covering's parts be so separate that the higher ones can be gradually transferred above the lower ones, in such a way that first a part can move from A to B, then both parts of the covering from B to C, then all the parts to D; the result is that as the weight gets heavier, it rotates on a shorter wheel, so that the times of transfer become equal. Then let clock wheels be added to the individual quadrilaterals,[218] so that there can be three wheels, and on each one the differences[219] of equations[220] as in the case of the planets—so that through the shorter wheel the movement gets faster the more the weight increases. In this way, after

214 This sentence first appears in 1560.

215 "impluvium."

216 The following two paragraphs first appear in 1554.

217 "proportio."

218 "tetramorphis."

219 "discrimina."

220 These "equations" describe what for Ptolemy were the differences between the regular or "mean" motion of a heavenly body and the irregular one, the mean motion being in a circular orbit, and the irregular one including reversals of motion etc. seen in the real observed path. Applying "equations" to the calculated mean path converted it to the real one. See on this Riccioli, *Almagestum Novum* (1651), 145b to 148d, and for an explanation and demonstration see http://faculty.fullerton.edu/cmcconnell/Planets.html, consulted on 17 May 2009.

the quadrilateral[221] of the first column, the second and then the third is revealed, and on the individual quadrilaterals the individual faces — the result is that faces and parts of faces are seen in the mirror, corresponding to the number of hours and parts of hours. All these features are seen in clocks with unequal hours, such as were used by the Romans.[222] In fact a wheel that rotates and has its axis of movement outside its centre will move the faster at the part close to the axis, the further the axis is displaced from that part by the centre of the wheel.

[428]A crystal prism possesses many of the powers of mirrors, in that it presents many images,[223] both those with their heads diverted downward and their feet upward, as concave mirrors can do, and those with single eyes and with four eyes. In such a prism, too, especially when it is &310 placed lengthwise facing the Sun, colours of great beauty[224] and beyond imitation appear, but when the crystal is put close to the eyes, particularly where there are trees and gardens at the time, it presents heavenly beauty — crowns, rainbows, tapestries scattered everywhere, glittering colours — pink, white, green, scarlet, blue, golden, and all mixed up and of very pleasing appearance; it displays a different likeness of things, aloft and turned away, as if plains were rising up into mountains. It also contrives a horizon, and districts, at a vast distance and looking attractive, like something it is not breaking up but recreating. The prism should be a big one, and the crystal extremely pure.

But now, leaving behind mirrors and the crystal, it is time for me to give an account of some false images produced by vision without manipulation[225] — I mean how two things can appear to be one. This occurs because vision sees correctly, in such a way that the rays fall onto the pupil orthogonally, or you might say perpendicularly, and are conveyed straight onto the convergence of the nerves.[226]

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221 "tetramorphim."

222 Mechanical clocks brought about a change in the way in which time was measured. Before the 14th century, the system of dividing a period of one day and one night into 24 equal hours was used only by astronomers. For most people, the periods of daylight and darkness were each divided into 12 "temporal hours," which therefore varied in length throughout the year. This is convenient with sundials, but the speed of a mechanical clock does not vary in this way. Cardano's description of the device here is obscure, but highly complex clocks had existed since the 1320s (Landes, *Revolution in Time*, 53).

223 "formas."

224 Reading "pulcherrimi" instead of the "pulcherrimos" of 1550, 1554, 1560, Nenci, and *OO*, since it relates to the subject of "apparent" and must be in the nominative case..

225 "synceri visus."

226 Cardano evidently refers here to the "optic chiasma," where the optic nerves from the two eyes converge and in part cross over. It was clearly described by Vesalius (Andreas Vesalius, *De humani corporis fabrica* [Brussels: Culture et civilisation, 1964] [original publication 1543], Book IV, chap. 4, 324, and figure on 318), though Galen's much earlier account had become lost and was only recovered from Arabic translation in the 19th century (see Galen, *On Anatomic Procedures: The Later Books*, trans. W. L. H. Duckworth

So when the eyes are slanted[227] so that the nerves are diverted up and down, two things will be seen as one. And in general, any items that are seen as marked out by position, form, size, or colour will appear as two even if they are actually one. This happens if one of the eyes is displaced, or if we look through diverse media; it is as if a spectacle lens[228] is presented to one of the eyes, while the other eye is seeing through pure air; or if a thing is partly in water and partly in air—it is reckoned as broken or as two things; or if something is placed in the middle between the eyes to prevent a &311 thing appearing as single—if it is not placed straight in relation to the eyes' position, so to speak parallel to them, or displays various colours, then two things will be reckoned to be there more securely than one. In fact certain things close to the eye present no obstacle, because they are smaller than the distance between the eyes; far away and close, they cover the thing seen. Furthermore, other things very close to the eyes do obstruct, yet things far away do so very little, because the angle they subtend is narrowed close to the eye because of the distance.[229] But change of position, not just in the eyes but on the fingers, not just in vision but on touch, commonly deceives by showing two instead of one. Indeed, with the index finger and the middle finger riding in turn upon it, a ball placed in the hollow of the hand registers as two, so much so that some people have made a bet in disputing over it.

On the same basis, things painted on a plane surface look solid. This mostly results from two causes: one is shadow, from which the eye makes the judgment mentioned; if there is shadow, the body too is shadowed and is a solid one. The senses have in fact grown so accustomed to judgment based on daily experience[230] that it is said that on recently discovered and never inhabited islands, the birds do not fly off and can be caught by hand.[231]

Another point is for you to consider what part of the body is being seen—for instance, in the case of a cube, the front upper part, the right one or the left; the other surfaces stay unseen. Then you will place the shadow in relation to[232] the illumination which you create in front of you, at an altitude of half a right

[Cambridge: Cambridge University Press, 1962]). On Vesalius see C.D. O'Malley, *Andreas Vesalius of Brussels, 1514–64* (Berkeley: University of California Press, 1964).

227 "obliquantur."

228 "conspicilium"—see n. in Book II at 182 (1560); translation is at present speculation.

229 It is difficult to reconcile all this together. The remainder of this paragraph first appears in 1560.

230 "usu."

231 The dodo on Mauritius fits the description here. The last accepted record of the dodo is that from the shipwrecked mariner Volkert Evertszoon, who in 1662 walked on to an islet that supported a small population of dodos. But this bird probably finally became extinct later, about 1693. For evidence consult D. L. Roberts and A. R. Solow, "When did the Dodo Become Extinct?" *Nature* 426 (2003): 245.

232 "ad."

angle,[233] but the body in proportion to lines which run out from the eye to the cube upon the plane. &312 You will be able also to establish the gaze from an angle, and the illumination from the side. Again, there is one basis for a panel[234] hanging on a wall, and another for one that lies under one's eye and hand, parallel to the horizon. But in all these there is this common feature, that you set up the thing itself in the same place, and express,[235] both to the eyes and to the illumination, the angles and the same points on a plane as the limits of the thing seen. When the angles have become equal, and are assisted by colours and shadows, they must reproduce the same bodies. The same thing reproduces the same thing, and a like thing a like thing. But remember to preserve a place of level[236] vision—it is the head of a human shape when a human being has been painted on a panel; whatever gets seen below that is low-lying, whatever above is high up, just as the eye will decide if they were really in such a position.

So to represent solids, there are the four following requirements to be met: the form of the thing derived from rays from the eyes, the shadow from the rays of light, the colour which should be just that of that particular body placed under that light and in that position; and finally, the position on the panel needs to be established, on the model[237] of a painted human being whose top[238] is in a straight line with your eyes. What else actually is a picture except an imitation of the physical states[239] in bodies, for a comparison[240] of illumination from a flat ground?[241] For even if the dispositions of the mind[242] can be guessed from a portrait, they are not expressed otherwise than through bodily states.[243] I said, "For a comparison of illumination," hence one level will be the face of a swimmer, of one who is under the Sun's rays, but another under some nocturnal gloom, another in the Moon's illumination, another in that of the &313 setting up of a candle,[244] which makes it a good idea to bring up a lamp for a trial.

Why are you astonished about illumination?—since some things are visible far away which pass unseen close to; for instance, on my iron purse a shape marked out with dark lines in a square is visible from a distance, but otherwise

233 "ad latitudinem dimidii recti."

234 "tabula"—presumably the surface on which the picture is painted.

235 "exprimas."

236 "aequalis."

237 "ratio."

238 "vertex"; Scaliger (*Exercitatio* 83 [318]) grumbles that this word in his opinion has to refer to a view looking *down* on the top of the head, to the "bregma," the anatomical term for the junction of the cranial sutures there.

239 "affectuum."

240 "comparatio."

241 "ex solo plano"—or it might mean, "from a plane alone."

242 "animus."

243 "corporeos affectus."

244 "alia candelae constituti."

invisible. Similarly, the stars too are visible at night but invisible by day. Hence too people help their work with a net.[245] At close quarters, even the tiniest mistake comes to light, and points the artist's hand towards precision.

Pictures are to be tested with a mirror, on almost the same basis. When things are actually shown "mirror image," this reveals much that had so far gone unnoticed. Arrangement can hide a lot, hence jewellers place pearls in a particular arrangement, putting the blemished ones in the middle and the most beautiful ones right at the ends, and they move down gradually from the most beautiful to the uglier ones, to prevent the ugly ones being identified by comparison. Meantime they put nearby some pearls that retain their attractiveness through correction[246] of their faults. Similarly, in an opposite fashion a mirror reveals flaws, turning round the original arrangement through which the picture was winning approval. It is like this with a mirror because it shows everything in contrary and inverted order; we can read letters written in reverse order when the mirror reproduces them correctly.

But to return to the picture: colours are not to be distributed casually, but if the dark ones are located among the bright ones and vice versa, they add charm and embellishment to the picture. So it will be right to put red [429]between blue and green, white between ash-coloured and saffron-coloured. But take care not to use white much &314 in pictures—it is like poison to them, because by its brilliance it starts by removing some attractiveness and seriousness from the work of art, and then darkens the other colours, and impairs the shadows of things.

Now[247] that we have got into discussing colours, we must speak about their generation and their names and sorts.[248] But because it is hard to cope with things with incomprehensible names, we will need to explain their names first, not at this moment from the view of antiquity, but so that our discussion can be understood. In fact to set out now to conform our discussion to the view of antiquity, amid their huge confusion about the names of colours, is a task outside our intention, besides being very difficult and involving vast pains. So we will attack this topic using an example admittedly novel, yet not useless. So I will now explain how colours should be dealt with, making a start from the most obvious points. The snowy colour resembles pure snow collected in a heap, of outstanding whiteness, and considerable brightness. The white colour is in lime, inferior to snow in brightness but not in colour. The milky colour is in milk, of less whiteness, and almost no brightness—in fact there is no whiteness without some bright-

[245] "reticulo"; this appears to have been a network of fine thread serving as a scale for visual work. See Nenci, 400 n. 81 for references.

[246] "mutatio."

[247] Material up to [B] on 320 (1560) first appears in 1554.

[248] "speciebus."

ness. These three are known by the name of "albus."[249] To it "niger" is directly opposite. This is the sort of colour there is in coals, which shines out from it. The Pramnian colour is named from the gem[250] which is like that. The silvery colour is named from silver and has much brightness, but little whiteness. The colour of lead is less striking[251] than white; it is darker, and has less light.

The watery colour is very like water—not sea water, but &315 spring and river water. It has much brightness, little whiteness; it is directly contrary to ashy-coloured, which is the colour of ash, in which there is more whiteness, but almost no light. Next to lead-coloured comes livid, which is precisely like the flesh of children thrashed with straps; it is similar to lead-coloured without any brightness, and is seen when the blood gathers and does not get out, but is collected below the skin. Straw colour is like the chaff of wheat. A brighter colour is that of urine from healthy bodies. Yellow is like ripe ears of corn.[252] Golden differs little from yellow, but is much brighter. Then orange-yellow[253] is like egg yolk, which we often refer to as "luteum."[254] Brighter than that is saffron-coloured, and a little redder. Flame-coloured, named from flame in the way that saffron-coloured is named from crocus, is much more gleaming[255] than that. Purple is the colour of our purple-dyed garments, more gleaming than red. Also very close to red is reddish[256]—it is like fairly gleaming wine. And it is clear that this colour is a little thinner and somewhat more gleaming than the colour of venous blood, which ought properly to be called red.[257] Rosy is made up from matt white and red mixed, and flourishes in roses, in boys and in girls, and besides in (among other things) cherries. Wine-coloured[258] is like the amethyst,[259] not named from

[249] The difficulty of mapping the colour words of one language onto those of another is highlighted here because English does not contain single colour words corresponding to "albus" and "candidus"; the old (1917) Lewis & Short's *Latin Dictionary* has in effect the nice distinction that albus = matt white, candidus = glistening white, ater = matt black, niger = glistening black. *OLD* does not reproduce it. But Cardano's use of the words later on (e.g. at 317–18 [(1560] in the present book, and at 709 [1560] in Book X) strongly suggests that he does adhere to it, and so I have adopted this for translation.

[250] Pramnian *wine*, from an island in the Aegean, is frequently mentioned by Homer as of high repute. The gem of that name mentioned here by Cardano was presumably of a very dark colour; see n. 289 below.

[251] "eximius."

[252] "aristis."

[253] "luteus."

[254] Pliny did, anyway: *Nat. Hist.* 10. 148, 29. 42, 33. 131.

[255] "clarior."

[256] "subrubens."

[257] "rubeus."

[258] "vinosus."

[259] A purple variety of quartz.

a wine, but drew its origin from bunches of grapes. A paler red,[260] like the flowers of pomegranate, is called "puniceus."[261] Green is the sort of colour in meadows in springtime before flowering starts, and emerald is the gem that displays it very beautifully, so long as it is a superior specimen. Lemon-coloured is named from the lemon or medlar, not very ripe, a colour mixed between green and straw. &316 "Prasius" is a colour derived from the herb "prasion," which is what people call horehound,[262] a little darker than green. Verdigris-coloured[263] is distinguished from it,[264] being so much more gleaming than green, the sort of colour that is often seen in cleaned-up verdigris. Sallow[265] is virtually special for poisons and snakes—it is green and black mixed, with added brilliance. After these come darker colours: "ceruleus" from wax,[266] like a calm sea, which is often called "Venetian" too. And blue,[267] derived fom the sky, as in select sapphires;[268] we shall call this celestial and cyan. There is also a stone of this name that painters use, entirely like sapphire but not glinting nor transparent. Rusty colour is from iron, which gathers rust. And dingy[269]—this is like the colour of earth which the farmer has recently turned over with his plough, and is darker than rusty; but neither of them is darker—neither of them glints.[270] "Melongeneus,"[271] as precisely in carcinomas, is so called from the fruit of a herb which is of this colour.

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260 "rubens pallidior."

261 This word classically means "scarlet, brilliant red, crimson."

262 The Greek word *prasion* (πράσιον) means either a kind of marjoram, or else horehound (*Marrubium vulgare*), which is evidently the meaning here. Alternatively, the word may be derived from πράσον, a leek, a vegetable of a dull dark-green colour.

263 "aeruginosus."

264 "adversatur"—does not I think here mean, "is its opposite".

265 "luridus."

266 "cera." But in classical Latin there is no such word as "ceruleus," derived from "cera" or otherwise, despite Cardano's fancy that it is associated with a *calm* sea; the colour is properly spelled "caeruleus," almost as Cardano spells it in the next item in his list, and this latter word is regarded as derived from "caelum," sky, as Cardano suggests.

267 "caeruleus."

268 Caley and Richards (*Theophrastus on Stones*, 136–37) adduce evidence that the sapphire of the ancients was not the transparent blue gem now called a sapphire, but dark blue lapis lazuli in which gold-like specks glitter (they are in fact iron pyrites). Note the reference here just below to a "stone that painters use, entirely like sapphire but not glinting nor transparent"; this appears to support the view that in Cardano's time too, "sapphire" was sometimes or often in fact lapis lazuli.

269 "pullus."

270 Meaning unclear.

271 Although this word is not in standard classical dictionaries nor Castelli, the modern official name for the aubergine or eggplant is *Solanum melongena*, the modern Italian word for it is "melanzana," and so the reference in this confusing account is probably to it and its colour.

There are then the four principal colours: white, red, green, dark. And let us establish seven more, in accord with Aristotle's view.[272] But now we must discuss their causes. All colours are generated from three things: the first is the substrate material; then the light, or rather the illumination, which is mingled with it; and the medium.[273] For things seen through green glass, or in the shadow of trees, very often look green although not really so. Also the look[274] of a thing is different when seen through water or crystal and when seen through air. Illumination also alters colour in proportion to its size, as on a pigeon's wing, because it glints with diverse colours in relation to the diversity of the light. A &317
substrate thing also in itself demands a colour from its own mixture—for black lime never occurs under any illumination, nor white coal. But this does happen, so to speak,[275] since they retain some light in potentiality or actuality: in potentiality as green, but in actuality as snowy white. There are colours that retain a lot of illumination: snowy white, silvery, golden, shiny white,[276] green, scarlet,[277] purple, and wine-coloured—almost all of them visible in an actual rainbow, if we inspect it aright. It is easy to put individual colours that contain a lot of light to the test. Place a jug full of water in the sun, and all of the many colours generated contain a lot of light. In addition, the colours seen in things that glint, such as in gold, silver, and water, which is a colour[278] shared with crystal, glass, and mirrors. Thus silvery is made from ash-coloured that has picked up a lot of light, just as snowy white is from matt white[279] mixed with much illumination, and

[272] Aristotle, *De Sensu*, 4. 442a23–32: "If, as is reasonable, one reckons grey to be a kind of black, there are seven of each [tastes and colours], for there remain yellow—to be referred to white, as oily was to sweet—with crimson, purple, green, and blue intermediate between black and white; and all other colours are got by combining these. Just as black is absence of white in the transparent medium, so salinity and bitterness are a deficiency of sweetness in nutritive liquid. Consequently the ashes of things which have been burned are bitter, for the scorching they have received has expelled their palatable fluid qualities."

[273] Cardano is loosely quoting Pseudo-Aristotle (*De coloribus*, 3. 793b33–794a2; Loeb 19): "So that all colours are a mixture of three things: the light, the medium through which the light is seen, such as water and air, and thirdly, the colours forming the ground, from which the light happens to be reflected."

[274] "species".

[275] "quasi."

[276] "candidus."

[277] "puniceus." Also see n. 261 above.

[278] Cardano uses the variant nominative form "colos" here, an alternative available in classical times.

[279] "albus."

scarlet[280] from shiny black[281] very full of light, as in hoar frost.[282] Purple emerges when dim matt white is mixed with the Sun's rays, as at dawn. Wine-coloured emerges from pure unthinned shiny black, mixed with air and brilliance.[283] Of the bright[284] colours, however, this is the one that retains the least light. Golden arises from pale yellow[285] filled out with much light. Green occurs in two patterns: either with much moistness gradually extracted by heat,[286] as in tree leaves, or when shiny black moistness is cooked to a further extent,[287] as when the black surface of standing water or earth blackened under showers turn green. When something turns green, air and light are mingled in with additional heat. Shiny white is made from pure matt white sprinked with medium &318 light. Watery is made from middling light and transparency—[420]transparency consists in actuality of no colour. If some dimness is combined with watery, a celestial or blue colour results, as in the sky. Some colours appear to be devoid of illumination, because they are present in things lacking glint, such as livid, matt black, and rusty. Matt black is shiny black without brightness—like ink,[288] and charcoal. "Pramnian," as I said,[289] when it is brilliant, is shiny black shared with these.[290] There is a colour without a name, like dark red in lacquer,[291] and we will call it "lacquery." Some colours, like blue and "prassian,"[292] sometimes admit

280 "puniceus."

281 "niger."

282 For the meaning here, there may be a clue in what follows, that the light at the time is inherently highly coloured.

283 On this colour, Pseudo-Aristotle writes (*De coloribus*, 2. 792b5–11; Loeb 11): "We must then base our assumptions and our examination of mixtures on what has been prepared before, for instance that the colour of dark wine occurs when sunlight rays are mixed with what is pure black and what is glittering, like the berries of the grape; for their colour is said to be wine-dark at the moment of ripening; for, when they are growing black, red changes to purple."

284 "lucidus."

285 "flavus."

286 "excocto."

287 "ulterius coquitur."

288 "atramentum"—can also mean "blacking" such as copper sulphate, used to blacken leather.

289 This colour is mentioned on 314 (1560), but is likened there only to a gem. The gem is presumably the same as the "prannium" in Book VII at 472 (1560).

290 "communis est illis."

291 "lacca"; this or the similar word "lac" indicate a dark red secretion produced by various insects and used in the past for the dyeing of wool. Castelli refers to lacca as an Arabic word = λάκχα meaning a viscous fluid, with refs. to Hofmann and Libavius, though he does not state a function for it.

292 "prassius"—see n. 262 above on the vegetable of similar name, also n. to Book VII at 437 (1560); as noted there, Castelli offers "nomen lapidis, vel gemmae viridantis, vilioris turbae, Smaragdi Domus, vel palatium dictae, quia hic in illa, veluti inclusus,

light and sometimes have none. Matt white occurs when wet things such as leaves dry out, or if they undergo degeneration,[293] like bread, and the hair in old age, and in disease, and generally in the weak. Goats and oxen of this colour are reckoned worth less and weaker than the shiny black or rust-coloured ones. Grey hair in fact occurs when moistness rots, and gets porous[294] because of the rot, and because of the porousness air gets in.[295] We stated previously that total rot does not occur in degeneration, but because it is moderated by coldness. Things get matt white from excessive dryness, as in lime and in burnt bones. Also, some things get matt white through unconcocted moistness, such as bones and roots. Likewise some marrows, such as the spinal cord;[296] also the brain and the bones. Shiny black occurs through combustion of airy or earthy moistness—airy certainly, like printers' ink, which is made from the soot of linseed oil. Again, charcoal and soot are earthy. Shiny black also occurs from a mixture of earth and water with the exclusion of all air, as happens under &319 showers in shadow.

These then are the causes of colours, from which it is easy to grasp why in the case of quite a number of animals the hair colour is of a shinier black from the start than it is as age proceeds; it is because the heat in the womb is more effective, and the moistness is more fatty, because as time goes by it is thinned out with wateriness. The evidence is that at birth no animal gets shiny black hair,[297] then with the passage of time the hair gets red or yellow. We ourselves, as our mother reported, were born with thick and very long shiny black hair. But why do not animals have green body hair or head hair? Nor any have purple or wine-coloured hair? A hair, being compact and of thick substance, can barely accommodate any light—but colours need a lot of light, as has been made plain. However, golden hairs occur, because they are scattered and yellow[298] and take

reperitur." Prassius is also a green gemstone; *L&S* notes praſius (one S in middle) = "prase," πράσιος (λίθος), a precious stone of a leek-green colour, and cites Pliny. *L&S* note the existence of πράσινος = leek-green, and πράσινος λίθος = πρασῖτις = a precious stone, probably the emerald, from Theophrastus. "Prase," πράσιος (λίθος), is a precious stone of a leek-green colour; πρασῖτις is a precious stone whose unclear identity is discussed by Caley and Richards, *Theophrastus on Stones*, 137–38.

293 "situs" = neglect, disuse, stagnation etc..

294 "rarescit."

295 Aristotle, *De generatione animalium*, 5. 4, 784b11–14: "mould is in fact the putrefaction of earthy vapour. So too the nourishment in the hair, being of this kind, putrefies if it does not get concocted, and what is called greyness results. It is white, because mould too is white."

296 In Latin its name is "medulla spinalis," the spinal marrow.

297 The text here reads "ab ortu nulli animali fiunt pili nigri." But Pseudo-Aristotle (*De coloribus*, 6. 798b20) in the Latin translation cited by Nenci, wrote, "*Non*nulla enim animalium statim ab initio fiunt nigra." So Cardano evidently perverted his probable source, who wrote that some animals *do* have black hair from the start.

298 "flavi."

up illumination, especially if washed quite often. The golden colour occurs from yellow lit up.[299] There are principal colours — matt white, saffron-coloured, purple, scarlet,[300] green, blue, shiny black. They develop from various materials, but metallic ones are longer-lasting and often more lively; matt white comes from white lead,[301] red from cinnabar,[302] blue from the cyan stone (the common people call it lapis lazuli), yellow from orpiment,[303] shiny black from earth of that colour, green from rust. Purple used once to be made from the blood of the fish "murex."[304] This kind of purple was extremely brilliant, and well known to kings, and far different from our own, which is made with a berry.[305] Vergil wrote,

> And the cloak was aflame with the Tyrian murex.[306]

The whole of this shellfish's blood is not suitable, but only the part in the throat used to be harvested, and from the living animal; the brilliance and attractiveness used to pass away by its juice, along with its &320 life. The shell is cone-shaped, reddish inside, provided outside with a kind of scattered spines, and ends in a point. Africa once used to provide a blue one, Tyre a red one; now it is no longer in use, and I am not sure why. It would be a good thing if it were recovered; it was really a more costly and pretty dye than the berry.

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299 The question of hair colour, in man and animals, is addressed by Pseudo-Aristotle in *De coloribus* 6, but at greater length and with so many divergences that here Cardano can in no sense be said to have copied Pseudo-Aristotle's account.

300 "puniceus"; see n. 261 above.

301 Lead carbonate. On its manufacture and use in antiquity, see Caley and Richards, *Theophrastus on Stones*, 187–91.

302 See n. in Book II at 137 (1560).

303 See n. in Book II at 196 (1560).

304 A shellfish, source of the "imperial purple" or "Tyrian purple"; see Pliny, *Nat. Hist.* 22. 3 (Loeb 6: 295–96): "Moreover we know that clothes are dyed with a wonderful dye from a plant, and . . . Transalpine Gaul can produce with *vegetable* (my italics) dyes Tyrian purple, oyster purple and all other colours. To get these nobody seeks the murex oyster in the depths, offering his person as bait to sea monsters while he hastens to snatch his booty, and exploring a bottom that no anchor has yet touched, merely to discover the means for a matron to charm her paramour more easily and for a seducer to ensnare another's wife." Nevertheless, Pliny discusses at length the merits and distinctions of the types of this oyster elsewhere (9. 131). On present-day understanding of the chemistry etc. of this dye, there is a valuable current review by Christopher J. Cooksey with chemical and historical detail: "Tyrian Purple: 6,6'-Dibromoindigo and Related Compounds," *Molecules* 6 (2001): 736–69; and a Bibliography at http://www.chriscooksey.demon.co.uk/tyrian/cjcbiblio.html

305 "coccum," in antiquity an insect (*Coccus ilicis*), thought at the time to be a berry or gall (*OLD*).

306 *Aeneid* 4. 262.

But we will discuss the berry in the account of plants—let us now return to the debate about illumination, [B] addressing the question why we had said that rays evidently emanate from the whole of the Sun, and that the Sun itself is far larger than the earth—not everything has a straight shadow, and it is not summer everywhere all the time. But the reason for this is that though rays travel toward the perpendicular to the earth so far as it is flat[307] (this has to be admitted), still these rays are not directed towards the centre of the earth. Hence, since the earth is rounded and not flat, the rays that reach us from the location of things that lie upon the earth are not arranged so as to be perpendicular. Hence the Sun from the North touches only the tip, as if from a point, so it cannot make southerly shadows. You will easily model this with a figure if you mark out two circles, one smaller, one larger. With lines drawn from the centre in the smaller one, you can advance a little outside the circle itself, and you will see whatever has been outside (consider people, plants, towers and mountains), and in how tiny a space can be enclosed what can receive rays on both sides from the greater circle. So the only people who will have straight &321 shadows are those who live within the half part, that is, the part lying directly below the Sun over a distance of 350 stadia.[308]

Anyone[309] will be in doubt, since Ptolemy defined a degree as 500 stadia,[310] and others[311] as 700. This occurred because Ptolemy defined the trip by a straight line, but Eratosthenes as "commune."[312] But to return to my plan: it is also often asked whether it is not summer everywhere, since everywhere on a plane surface the rays fall on the countries along the perpendicular.

But you will say, "They aren't along the perpendicular; they don't actually make for the centre of the earth." But this does not appear to be enough, since the theory[313] of reflection is reinforced, as we showed, from the fact that a ray returns into itself. But it is the earth's size that brings this about—even plane mirrors reflect to the perpendicular if placed on their backs on the earth. But this is not true—instead, rays reflected elsewhere make for the opposite side of the Sun. So how will perpendicular reflection happen from plane mirrors? Since it was exposed to the Sun in such a way that its surface, if regarded as extended as much

307 "ut plana est."

308 Say 43 miles. On the interpretation here, see Nenci, 409 n. 100.

309 This paragraph underwent additions and alteration in 1560.

310 He unfortunately followed Posidonius in this misleading estimate.

311 For instance Eratosthenes, whose estimate was earlier and better. See E. Gulbekian, "The origin and value of the stadion unit used by Eratosthenes in the third century B.C.," *Archives of the History of the Exact Sciences* 37 (4) (1987): 359–63.

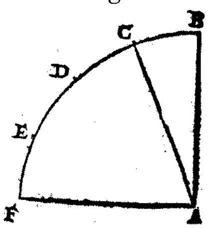
312 The meaning is unclear. The distances traversed in moving between two points on the earth's surface one degree apart by moving on the surface and by moving through the solid earth in a straight line do not differ by as much as one part in a million

313 "ratio."

as I may wish, is always parallel to a plane surface touching the Sun at a point, a plane surface through which a straight line passes which is drawn from the Sun's centre to the mirror's surface. So imagine that there are lines from the earth's centre coming to its surface and lying upon the planes at right angle—you will appreciate that these planes do nothing, so that the rays from the Sun, though it is much further away than the earth, are at right angles in the plane itself.

Bear in mind then that the Sun's rays come to us and to our plane surface,[314] and not on a perpendicular on the basis of the earth's centre, as they are not making for the earth's centre. Also that they are not, as it were, coming onto the erect face of a mirror, since the earth's plane is the plane onto which a perpendicular from the earth's centre falls. Also that this plane cannot be parallel to the Sun's well-known plane, &322 onto which a straight perpendicular line from the Sun's centre [431]comes. Then in neither manner will they also come to us at a perpendicular, and so it will not be summer everywhere.

It is clear from this that buildings can exist which even in winter warm up the air a good deal. They should not be constructed straight in relation to the



earth's centre, but aligned to receive the winter sunshine on the perpendicular. And so, to give you an example, let our dwelling be at A on the plane AF, which is on a perpendicular from our top to the earth's centre AB, which is accepted as being 44.5° away from the equator.[315] It will therefore lie 68° from the winter circle.[316] Let there then be the fourth part of a circle BCF, and let BC be 22° out of the 90° which are BF.[317] So the point C will be 90° from the Tropic of Capricorn. Hence, when the Sun gets there, an erect plane or a hollow cylinder with a surface AC will receive perpendicular rays at midday.[318] Let there then be an arc CE of 47°, and let the degrees be marked out in conformity with the Sun's declination on each day, and let the mass AC be moved backward.[319] In this way it will

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[314] "planities."

[315] The parallel of 44° of latitude north runs a little north of Florence, but Milan and Pavia lie a little north of the 45th parallel. It is not clear where Cardano was when composing this work, but the Dedication to Fernando Gonzaga is dated from Paris "in itinere", of course far further north. The difficulty in following the Figure here probably arises from one's predisposition to suppose that if one's house is at A, and that AB is on a perpendicular from our top to the earth's centre AB, then B must be at the earth's centre. But it is up in the sky; the earth's centre is somewhere far below A. The rest then falls fairly well into place; the side of the house can be tilted into alignment to face into the Sun at any period of the year.

[316] "hiemali," that is, "hiemali circulo"—i.e. the Tropic of Capricorn.

[317] A tropic lies about 23° 28′ from the Equator.

[318] "in meridie."

[319] I.e. probably being tilted to face the Sun.

receive perpendicular rays all the year round, so that you &c323 can have fruit and vegetables before their time, and the dwelling is made pleasant.

From these causes you now appreciate not only the double basis of perpendicular rays, but also the varieties[320] of shadows, which are altered in all bodies according to the position of the body, the sphere being the only exception—when it stays in the same place, and with the light too at rest,[321] it makes the same shadow. The other solid bodies are different; if rods are extended along the length of the Sun's rays, they make practically no shadow, apart from the amount of thickness the rod may have acquired. And if the rod is set up in such a way that its shadow is perpendicular above the shadow of another rod set up on a plane, then this shadow will be of medium size and precisely equal to the rod itself, apart from the amount it has departed through elongation from the earth's plane, because of the Sun's size—which however is a minimal amount—minimal in this way, that every body exposed to the Sun restricts[322] its shadow within a distance corresponding to the size of that body's diameter taken 109 times; this is the approximate ratio of the distance of the Sun from the earth to the Sun's own actual diameter.[323] This reveals a clear basis for discovering the ratio of the altitude of any star to its magnitude. By placing a sphere of known diameter on the top of a mountain, &c324 you will see at what distance its shadow ends, and compute[324] that the ratio of the altitude to the star's diameter is that of the straight-line distance between the place where the shadow ends and the diameter of the sphere.[325] So when you set up above the rod parallel to the plane—the rod that is to make a shadow equal to itself—another rod above the perpendicular,

320 "discrimina."

321 "quiescente."

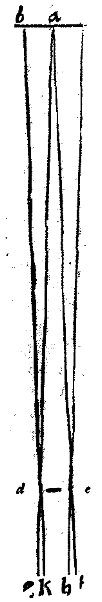
322 "finit."

323 This is because the Sun's diameter exceeds that of any body in the Earth's neighbourhood likely to throw a shadow, and if the body is round, the shadow will be conical. If the Sun's distance is measured from the tip of the conical shadow, the shadow will therefore have a length described by the stated relation. The Sun's diameter is about 865,000 miles and its distance from the earth about 93,000,000 miles. The ratio is about 107.5. The Ptolemaic system made it about 114.5, and the subsequent system of Al-Farghani (available in the Latin of John of Seville from 1137 and in that of Gerard of Cremona from 1175) made it about 111 (van Helden, *Measuring the Universe*, Tables 1 and 2).

324 "colligis."

325 This makes sense if we can assume 1) that "altitudo" is not an *angle* above the horizon here, but the distance from the Earth (more precisely, from the shadow's end—see below) to the spherical star, and if we can conceive 2) that a star would throw a *visible* shadow of the sphere placed on the mountain top, a shadow which would have an ending somewhere because the diameter of the star is greater than the diameter of the sphere. On 334 (1560) of this Book, Cardano remarks that "making out the end of the shadow is laborious and no small task." Then simple similar triangles indicate that the stated proposition is true.

in such a fashion that the Sun's ray itself falls straight upon it, then the shadow will become the maximal shadow that can appear with the existing[326] size and position of the Sun. This will be quite a lot larger than the rod's length, and this occurs because of the inclination of the earth's plane from the position of its surface upon which a perpendicular ray falls from the Sun's centre. All the rest[327] are established within these limits, and the causes of their large and small size are



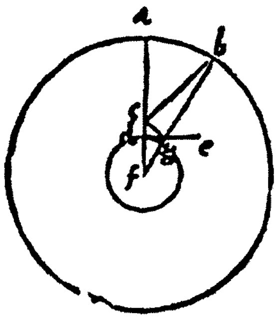
mingled, so that they are added to these simple positions to a greater or less extent.[328] But whether the rays are directed just from the Sun's centre or from its whole extent, any opaque object, however, large, makes an equal shadow, if it has been placed close to the perpendicular above the surface which lies perpendicularly above the plane close to the total inclination—for because of the distance, &325 parallel rays embracing the opaque object travel precisely in both ways, if from the Sun's centre because of the infinite proportion AD and AB to DE, or if from the whole Sun because of the maximal proportion CE and BD to BC, the shadow gets somewhat shorter than the opaque object over a long distance—because the rays CEH and BDK barely diverge from parallel. So whether you settle for the former or the latter in that position, the shadow always appears equal to the opaque object.

But let me return to the altitude of the Sun and the other stars. It is something to marvel at, why when we make a journey all the stars seem to follow us, and river banks fall away from us and move back while we go past in a ship. The reason is not obscure: as the distance of the stars bears a huge ratio to the whole size of the earth, our progress cannot alter the position of a star. We have in fact explained already that the eye does not perceive that this is as if it were not the case.[329] So when a star, for instance, precedes us by the magnitude of a cubit,[330] and when we have advanced through three miles in succession, the star should &326 appear to precede us by the magnitude of a cubit, because three miles in succession create [432]no detectable angle with the altitude of a star. So as we go ahead so that the star always seems a cubit ahead of us, it must seem to move with us, and on the same basis things behind our backs must appear to follow equally. But if you look at another man walking, and you are at rest, these things will not appear to be moved. But stars will not occupy the same position in relation to your eye, because of the diversity of their appearance—some star will appear to have left behind those

326 "tali."
327 It is not clear what these are—rods?—they are feminine plural.
328 The remainder of this paragraph first appears in 1560.
329 The location of this previous explanation is not apparent.
330 On the cubit, see n. in Book I at 26 (1560).

that were previously in front[331]—since this cannot happen to ourselves, but for us to see stars always in the same position in relation to our own that they were in previously, they must appear to come along with us for this reason and accompany us all the time. But although we may think we are stationary in a ship, then as it moves on, what was in front gets left behind. So when our eye detects the movement, but thinks we are stationary, because we are stationary in the ship, it[332] has to judge that river banks and trees are moving towards us, and then are behind, on the opposite basis to the movement of the stars.

For the same reason there is room for uncertainty, though in contrary fashion, about why when the Sun's rays move round[333] the whole circumference of the earth, and the Sun moves round heaven, yet the Sun does not appear to move in heaven, nor do its rays appear to move on earth, since the rays themselves travel forward at least a thousand miles per hour, if not more.[334] The reason in relation to the Sun is that the circle in which it rotates does not look large to the eye, and so the movement looks not large. And it does not seem &327 to be moved, since it proceeds little by little, and the distance it is seen to traverse is very small—and, to put it more clearly, the angle it creates through its motion by the individual movements is imperceptible—so in accord with the added details[335] we explained before, the Sun will not appear to be moved, nor on the same basis will any other star.



You[336] will perhaps object that if the Moon is carried round on the surface of the Earth, it would appear to move very fast. But does it move faster in heaven, and in accord with the same proportion? Suppose it is moved from A to B; the eye C agrees that there is a great proportion to DF; let something also be moved in the same period from D to G, in such a way that G is in the line BF. Then I say that the motion from D to G appears faster than that from A to B—indeed, the angle ACB is a little larger than the angle AFB,

[331] "nam aliqua videbitur post tergum reliquisse quae ante erant"—the syntax does not support the translation, because "reliquisse" must be transitive, but I cannot see a clear alternative subject here.

[332] The eye, presumably.

[333] Translating "circumeant" rather than the "circumeat" of the text.

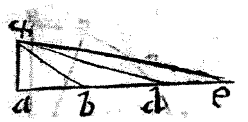
[334] Take the earth's diameter, following Cardano, as 10,000 of his miles (212 [1560] in Book II), multiply by π to obtain the circumference, and divide by 24 to obtain the distance travelled by a point on the Equator per hour: about 1310 miles. Points north or south of the Equator travel proportionately more slowly; at a latitude of 45°, in the region of northern Italy, they travel at about 926 miles per hour.

[335] "supposita."

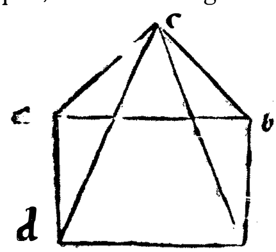
[336] Material to [C] on 329 (1560) first appears in 1560.

because the angle CBF is almost imperceptible, because of CF being small. So if it is supposed that AFB is imperceptible, so will ACB be. First, then, let what is found be the angle ACB and the arc ACB, so the movement was imperceptible previously. But because CG is quite imperceptible compared to BC, and facing BG the angle BCG will virtually be a right angle, therefore the angle DCG will be too, from the statements in the first Book of the Euclidean *Elements*. So DG will be much larger than &328 DC, because D is a right angle; in fact the angle DGC will be nearly equal to the angle ACB, and so D will manifestly appear moved to G, and much faster than from A to B.

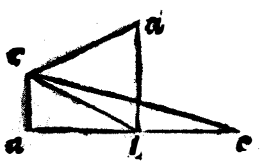
It follows from this, that the further things are away, the less they will appear to move, even if they ought to appear moved genuinely faster and in proportion equally. Indeed, the line from C extended to the point in the line FB, the further away it gets extended, the less it makes the angle CBG; hence since F is the same, ACB will be less; but BCG will not be increased, because CG is imperceptible. So DCG will be increased, and the line DG in comparison with DC. Likewise too in a plane in which something is moved further away, it seems to move more slowly. Let there be three equal lines, AB, BD, and DE; the eye is at C: I say that



the &329 angle ACB is larger than the angle BCD, and BCD than the angle DCF. Indeed, the proportion of DC to DE is greater than that of BC to BD, because BD and DE are equal, and CD is larger than CB, and similarly CB is larger than CA, because the angle A is a right angle, and CBD and CDE are obtuse; therefore CD is greater than CB, and CB than CA. Since therefore the angle ABC is greater than BCD, and BDC is greater than DCE, it follows that the angle ACB is greater than BCD, and BCD greater than DCE; so AB will appear larger than BD, and BD than DE.

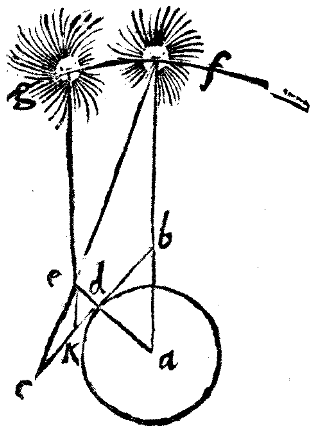


But if the motion is sideways, the same principle[337] applies still—the angle ACB is greater than the angle DCE, so the line AB seems greater than the line DE. But if the same distance is traversed straight and sideways, the one that is moved straight will seem to move faster—faster, for instance, from B to D than from A to B, since when the two lines BC and BD are equal to the two lines BC and BA, and the angles A and ABD are right angles, of those mentioned the angle BCA will be greater than the angle BCD; therefore the line AB will look larger than BD—which is what we proposed. But if the motion is from the same point—suppose from B in a straight line to E, but sideways to D—I say that



[337] "lex."

BD will look larger than BE, on the assumption that they are equal. The two lines BE and ED are indeed equal, and BC is in common, and CE is larger than CD, so the angle DCB is greater than BCE, since [433]DBE[338] is a right angle, and CBE obtuse.[C] But another basis applies to the rays, for by their movement they create a perceptible angle at the eye, and consequently should seem to be moved. The reason they do not is this: suppose there is the earth with its centre A, and a flat surface of it, as I said, which carries the point D, but to us it is BC because of its magnitude, and there is a &330 tower which is perpendicular above the plane DE, and with the Sun at F, which while extending the ray FEC extends CD. And when the Sun has moved on to G, extending the ray GEK, it leaves behind the shadow KD. So since the movement is assessed by the shadow, the Sun will appear merely to have passed from C to K while it is moving from F to G, but the interval CK is small when compared to the altitude DE, which is small. So, since it moves gradually and traverses only the interval CK, suppose in a quarter of an hour by a single movement, it will traverse no interval capable of creating a perceptible angle; so from this detail often repeated, the ray FC will seem to be always at rest while it is being moved.[339] Let us suppose for instance that when the Sun is in the seventh part of Taurus, around the hour nineteen and a quarter, the shadow is equal to the gnomon; at 21 hours minus a quarter, it is double; so it is doubled in an interval of one and a half hours. So its motion corresponds to the length of the gnomon, not to the velocity of the Sun.

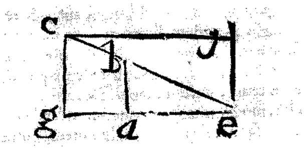


But you will say: "Why does the ray not appear to move?" I understand the cause—but I do not understand why it traverses so much space &331 without appearing to move. It is in fact accepted that at sunrise and sunset the shadows change very fast and with the greatest increases and decreases.[340] So let the

[338] *OO* and 1560 read DBC, but DBC does not appear to be a right angle, and Nenci notes this and reads DBE.

[339] The remainder of this paragraph together with five subseqent ones first appear in 1560.

[340] Nenci cites here Pseudo-Aristotle (*Problemata*, 15. 9, 912a34-b3; Loeb 1: 339): "Why does the Sun produce long shadows when rising and setting, but smaller ones when high in the sky, and smallest at midday? Is it because when rising at first the Sun will produce a ray parallel to the earth, and cast it to an infinite distance, and next a long shadow; but this will grow less and less because the straight line from the Sun above continually falls farther and farther inside the triangle? . . . The shadow, then, is least when the Sun is highest, at the point, that is, where the Sun is overhead." The same work (*Problemata*, 15.



setting sun be C, a plane GE, an erect body AB, the end of the shadow (the same as the start of the rays) E, another erect body EF, in which the motion of the shadow is imperceptible, since only when the Sun sets do the rays cease to illuminate. And they themselves will be at their clearest, because the angle CFE is a right angle. But no one can doubt that as seen from the point E, both the rays and the shadow are carried along in the plane GAE with incredible speed around sunset; indeed, the shadows have to move as much more as a point on the Earth's surface moves as seen from the region of the Sun's centre.

But in the previous Figure,[341] if F is placed at sunset, the angles FAE and FEA will be virtually right angles, because of AE being small and of the theory of triangles inscribed in circles in relation to the arc and chord, as they call them. Thus there will be angles of the line FC, angles with two lines emerging from the centre A towards it, the one line, of which AD belongs, the other such as AK, and these angles will almost be right angles; so that shadow which is subtended and which is very large, is very small.[342] So that very large progress will not take place unless DE is very long, which is impossible in comparison to AD. Another reason is that the larger &332 AE gets, the more the strength of the rays is reduced, on account of the small size of the angle AEB. So neither the shadow nor the ray is distinguishable; consequently in uncertain light, the light itself is not perceptible, and the shadow, which is made out because of the light, much less so, and the size of the shadow even less so, and lastly, the movements of the shadow or the rays still less so.

You will say again, "How will the shadow get endless instantly,[343] if a very large one is small?" It is linked to the shadow of the Earth's roundness, which is very large, and so from small it gets endless in a moment. As there is no body present in the plane, the dispersal of both light and shadows is very rapid, but because the light during both twilights (so to speak) is uncertain, and the gap that is seen by the eye as lit is small, when either change occurs, the movement is instantly concealed, as was shown in the second case.

It is also not clear why this illumination always looks tremulous on the Earth. Is it on account of some point already mentioned? The reason, as has been said, is that it is in motion but does not seem so; so some intermediate level is perceived. The same also occurs through ambiguous vision;[344] the actual end for

5, 911a14–b21; Loeb 1: 331–35) also seeks to demonstrate why the rates of movement of the shadows vary with time of day. The text of material present here only in the editions of 1550 and 1554 is available as Appendix 3 in Nenci, 421.

[341] Ignoring a superfluous "quoniam" in the text.

[342] Here the meaning and syntax are obscure.

[343] "statim."

[344] "ambigua visio."

shadow and illumination is neither shadow nor light, and anything whose movement is uncertain is regarded as trembling, for reasons already given. But why does the hand of a clock not look tremulous? Because that motion is not perceptible in any way, being slow; for them to tremble visibly, things should not move so slowly that they look entirely at rest.[345]

With this recognised, a larger issue follows on, in which human &333 subtlety instructs us how to measure the distance of all stars so easily that that no one has the parts of his home so readily to hand.[346] Since actually in the figure of the Sun's motion its altitude F has been determined, either by planisphere or by armillary sphere[347] or other instrument, and by tablets, when this is deducted from 90 degrees we will have the angle FAD, but the angle CED is known by theory and measurement, whether C is the end of the shadow or is the eye. So the angle FEA is known, hence (from Euclid's account in the *Elements*) the angle F, and the ratio FE of the altitude[348] to AE, half the Earth's diameter, of which we proved the size previously. It is in fact five thousand miles.[349]

The rod DE ought to have a steel circle at its bottom to rest on, at a right angle. Then the circle ought to be exactly plane at the lower part, so that when it is applied to a plane, you would know whether the plane was really so. And it would have lead plumblines[350] above from its four sides, and be of known magnitude from its uppermost tip right to the bottom of the surface of the steel circle. Then when the rod is fixed as far as the circle, and the plane is adhering to it all round, and the plumblines have [434]stuck to the rod, the plane is really so, and the kind of plane to which a line drawn from the earth's centre is perpendicular—and this plane is suitable for obtaining an altitude. But if, while the circle adheres to

345 This question of the basis of trembling or shimmering was addressed by Pseudo-Aristotle (*Problemata*, 15. 13, 913a5–16; Loeb 1: 343–45): "Why does the edge of the shadow cast by the Sun seem to quiver? It is not because the Sun is moving; for it cannot move in two directions at once, and this is implied by quivering. Moreover, its change of position is imperceptible, as is also that of the Sun itself. Is it, then, due to the movement of bodies in the air? These are called particles. They can be seen in the rays passing through shutters; for these move even in a complete calm. As they are continually travelling from shadow into light and from light into shadow, so the boundary-line which belongs both to light and to shadow seems to be moving in a similar way. For these particles are changing position both at the point where they cause a shadow and at the point where they cause light. So that the shadow seems to move, though it does not move in this way itself, but they do."

346 The text of material present here only in 1550 and 1554 is available as Appendix 4 in Nenci, 421.

347 "armillis."

348 Or distance.

349 Earth's diameter is discussed in Book II at 211 (1560) and Book III at 256 (1560).

350 "perpendicula."

the plane, the plumblines do not, or while they do, the circle is not touching the plane at some point, that plane is not suitable. So if you want to avoid this worry, &334 fix the rod at a perpendicular to a large board that is plane and smooth,[351] and then wherever you will have placed the board so that the plumblines touch the rod, convince yourself that you have found a plane suitable for you. If later on you would like to know the magnitude of a star too, you can discover it from the end of the shadow, as I said before, when you have already obtained its altitude. But since making out the end of the shadow is laborious and no small task, you will achieve this very easily another way, especially in the case of stars other than the Sun and Moon. Take the diameter of the star with a planisphere,[352] double it, and add a nineteenth part to it; and with this divide every time[353] 7,200—the number emerging is the ratio of the altitude to the diameter; so since you have now worked out the altitude of the star and the ratio of the altitude to the diameter, it is clearly the case that the diameter is known. Let us suppose for instance that the star's diameter is nine and a half minutes; I will double that, and get nineteen minutes. To these I will add every time a nineteenth part, on account of the magnitude of the diameter on the board,[354] and there will be twenty minutes. I divide 7,200 by this, and they are the minutes of the diameter, and 360 emerge. And so it is clear from this that the diameter of this star is a 360th part of its altitude.[355] So the usefulness and the subtlety of study of rays is evident from all this; I shall now abstain from the rest of the calculations, such as those I will cover in the twelfth book of the complete work.

[351] "tabulae planae et leni magnae."

[352] Estimating the diameter of stars by eye prevailed until the use of the telescope in Galileo's hands just after the time of *De Subtilitate*, and looked credible because of diffusion of the star's light within the eye and elsewhere, though the stars are points of light at a vast distance away, and their apparent diameter is more a function of their brightness. As Galileo wrote, "They appear larger than they would if stripped of those adventitious hairs of light, for the angle at the eye is determined not by the primary body of the star [or planet] but by the brightness which extends so widely about it" (van Helden, *Measuring the Universe*, 66).

[353] "semper"—but only once in the example following.

[354] "tabula."

[355] I cannot follow the basis of this calculation.

[434] &335 Book V On Mixture, and Incomplete or Metallic Mixed Things

So far, approximately five parts of the whole work are complete: that is, the first one about the more occult principles, matter, form, the vacuum, the union of bodies. The second is about the elements, since they were the complete, absolute, and manifest principles. The third is about heaven. The fourth is about light and illumination. We have not entirely finished a fifth part,[1] which is about the things that are visible,[2] since much is missing that concerns the ears and the other senses, as well as the mind and also the eyes. So our topic now will be mixed things; mixed things in fact need those primary things, and an element also needs heaven, and illumination and light—therefore we dealt with these first. Mixed things need heaven, and one can understand from obvious reasoning how much the state[3] of heaven can influence what is here below. Indeed, flour milled in August from wheat usually keeps unspoilt for us a whole year. And people say that beer made under the Moon of March lasts all year, though in summer it stays unspoilt for twenty days and in winter for two months. They say that beer from Danzig[4] lasts for ten years, and sometimes for twenty, without turning bitter or mouldy, because it is made from March[5] water. Another reason is possibly that in the month of March the seeds of the wild hop[6] are still alive, and &336 then the moistness is clearly consumed; it is a time very far from the time at which that seed was gathered, and for that reason the seed is effective

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[1] This "fifth part" perhaps ultimately became part of Book XIII, which is concerned with the senses, what can be sensed, and pleasure.

[2] "apparent."

[3] "constitutio."

[4] "Gedanense," which *OO* reads, is a more orthodox spelling than the "Gedavense" of 1560 and Nenci. This sentence first appears in 1560.

[5] Probably water drawn in that month, as Nenci argues (425 n. 1).

[6] "semina lupi salictarii": probably seeds of the wild hop; see Plin. *Nat. Hist.* 21. 86 (*OLD*).

and very free of moistness. It can make "biria" or "cerevisia" (that is the name the Germans have given to beer). The seed is effective at that time, since it usually sprouts then. There is unlimited experience of this matter, for the Vergilian[7] herbs rise and decline with the stars of the same name. But I must make this point again on its own: all these mixed things consist of earth and water and celestial heat, with man the sole exception. Part of them lies hidden below the earth, another in the waves, another above the earth; but my present purpose is to talk about the things that by nature lie hidden.

All the mixed things without movement under the earth or the waters are divided into four kinds: earths, juices, stones, metals. That no more can exist is shown from this line of thought:[8] for example, there are those that melt and then return to their own shape and stay hard—these are called metals.[9] A metal is actually nothing but a thing that can melt, and when it reverts it stays hard. I understand the word "hard" in two senses: first, what does not readily yield and is not readily broken. Everything that can be drawn out is a clear example; hence pitch can be drawn out without resistance; crystal resists, and antimony is better, but they cannot be drawn out, and so are readily shattered by a blow. What melts and on reverting is not hard, is called a juice.[10] What does not melt at all is either hard and is called a stone, or is soft, very easily passes over into tiny pieces, and is called earth.

&337 In addition to these four,[11] however, there are a number of other kinds of things mixed out of these. Anyone capable of calculating correctly will find that there are eleven,[12] and that no more can exist. Examples of the simple bodies are: [435]sulphur as an example of a juice, crystal as one of a stone, Lemnian earth[13] as one of an earth, silver as one of a metal. I shall present instances of the compound ones in their own place, so that I do not have to do much useless repetition. Examples of the simple ones were essential, because I am not going to deal with everything at the outset. For I term "perfect" all that stays solid, such as

[7] "Vergiliae" means the star clusters normally called the Pleiades, and the word is not associated with the poet Vergil. Pliny (*Nat. Hist.* 18. 251–53) waxes lyrical on the generosity of Nature in providing these as signals to the husbandman on how to conduct his agriculture.

[8] "argumentum."

[9] Scaliger (*Exercitatio* 88 [325]) complains that Cardano has forgotten the metal mercury here.

[10] "succus."

[11] I.e. earths, juices, stones, metals.

[12] This is the number of different ways of picking 2, 3, or 4 from 4 items—six different ways of picking 2, 4 different ways of picking three, and one way of picking all 4. Here they are: juice + stone, juice + earth, juice + metal, metal + stone, metal + earth, earth + stone; then juice + earth + stone, juice + earth + metal, juice + stone + metal, earth + stone + metal; finally juice + stone + earth + metal.

[13] On Lemnian earth, see n. in Book II at 194 (1560).

metals and stones, about which I will speak later. Softer things are "imperfect," as I name mixed things, juices, and earths; I shall name them all "metallic," so as to distinguish stones from metals. I shall now begin, then, to open my account of metallics, starting with the kinds of earths.

The kinds of earths are distinguished according to colour or odour or use. We have spoken above about those that are distinguished by use. About the others that are distinguished by colour, the debate is over; what remains is to cover the use of some of them, and also the odour. Fragrant earths are uncommon, stinking ones are common. All those that stink are mixed with metallic particles. However, Agricola relates that at Mariaberg in Saxony[14] while silver was being dug out of the silver mine of Saints Sebastian and Fabian in the presence of Henry, Prince of Saxony, such a fragrant odour burst forth that the Prince cried out that Calicut[15] was present—it is in fact a town in India which exports all fragrant things.[16] In Malacca, a harbour of East India,[17] &338 vessels are manufactured from highly fragrant earth, but are on sale for a very low price because they are plentiful—or perhaps instead because all powerful odours, however good among things unsuitable for eating, make food unpleasant, and so to speak take the life out of it. Pleasant foods are in fact so because of their own odour, a moderate one. When this is drawn out and overcome, it blows away[18]—hence it leaves the thing tasteless and unpleasant. This can be tested with a cake[19] stored in a cypress vessel, even if frankincense is added. Other things add attractiveness. But instances of evil odour are more common, and these are so bad as even to be destructive.[20] At a silver mine at Annaeberg,[21] which was called Rosy Crown, as the same man[22] tells, twelve people were suddenly suffocated—hence it was abandoned, in great fear in case evil demons inhabited it. People were actually convinced of this, since it happens from a smell of earths or stones; once in the brain, it kills instantly, and it is not surprising that many foul things lurk in the earth's bowels, just as animal dung does.

[14] Mining town also known as Marianopolis and Marienburg, and situated in Saxony in Germany.

[15] "Calecutum."

[16] Nenci has identified the source of the statements about Marieberg and Calicut as Georgius Agricola, *De natura fossilium*, lib. 1, 174. The following five sentences first appear in 1554.

[17] The Strait of Malacca now separates Malaysia and Singapore from Sumatra.

[18] "exhalat."

[19] "torta," identified in DuCange as a Low Latin word on its way to becoming a "torte."

[20] "saeviant."

[21] Annaberg in Saxony in Germany.

[22] Georgius Agricola, in his *Bermannus, sive De re metallica dialogus*, 432–33, cited by Nenci; he reported that the mine was abandoned on account of this accident, though still rich in silver.

But not just foul things—also materials of any kind are underground, with various uses. For example in Britain shiny white earth used to be dug out of wells, no less than a hundred yards[23] deep, and after you had taken the silver out of it,[24] fields were scattered with it and made so fertile that to have scattered it once in a lifetime would be enough.[25] And so all the earth that is unseen, like the bowels of human beings, is of use to someone. But generally we overlook investigation into these issues, partly through ignorance and partly through greed. Everywhere—I mean in &339 towns, not to speak of fields—there are diverse stones under the earth, and kinds of earth with various uses and of various colours, mostly metallic kinds—but we seek them only in the mountains. What shows that this is so is that countries once regarded as infertile, such as Germany, are now very productive of silver; others have stopped being so after having been productive. The reason is that though metals and stones and juices are everywhere,[26] as earth vanishes with the passage of time they come to light; others get hidden as the earth increases, as Anaxagoras[27] appears to have said correctly, that (as it were) everything is in everything,[28] but in the mountains is out of line with any opportunity of usefulness, because the waters are readily run off to places lower down, if any are available.[29] In agricultural land we will begin by drying up the water flowing under the ground, since there is not much of it, by draining it off, and then we will use a wall or rocks to obstruct and block off the places from which it flows. In this fashion people dig mines even under water, to overthrow towns, and to defeat actual moats[30] by digging under them. On a different plan, we empty

[23] "passibus"—but the original Pliny reads "in centenos *pedes* actis plerumque puteis."

[24] "postquam argentum detraxisses"—but Pliny wrote "creta argentaria" = *chalk used to clean silver*.

[25] The Loeb translation of what Pliny wrote (*Nat. Hist.* 17. 45; Loeb 5: 31–33) is: "Another variety of white marl is the chalk used for cleaning silver; this is obtained from a considerable depth in the ground, usually from pits made 100 feet deep, with a narrower mouth but with the shaft expanding in the interior, as is the practice in mines. This chalk is chiefly used in Britain. Its effect lasts for 80 years, and there is no case of anybody having scattered it on the same land twice in his lifetime" (Pliny had mentioned just before the use of marls as agricultural improvers, lasting up to 50 years).

[26] This is not precise enough for Scaliger, who (*Exercitatio* 91 [326–27]) protests that these items cannot be literally *everywhere*.

[27] See n. in Book II at 148 (1560).

[28] This Athenian philosopher (about 500–428 B.C.) wrote a work preserved in large part by Simplicius (a Neoplatonist of the sixth century A.D.), which opened with the words "All things were together," and maintained that there was a portion of everything in everything (except mind). See Kirk et al., *Presocratic Philosophers*, 365–67; Simplicius, *In Aristotelis Physica*, ed. H. Diels, CAG 9–10 (Berlin: Reimer, 1895), 1439–40 (index linking all fragments of Anaxagoras).

[29] The meaning is obscure.

[30] "fossas."

rivers by diverting the water along detours; according to Herodotus, Cyrus is taught to do this too by Croesus, diverting a river lower down into the previous bed.[31] In the same way it will be feasible to divert even underground streams in some other direction, directing them back into the same channels, so that in this way we can excavate under the water. There are also places lower down into which we sometimes transfer water, not bringing it back again;[32] this is a protection it is particularly permissible to employ in mountains, because of the height of the location. In fact the water found everywhere underground is neither very deep nor on the level[33] nor continuous. The foundations of walls and dwellings show &340 that it is not deep, and they usually reach the earth below water level. That it is not on the level in height is demonstrated by the diverse depths of wells. That it is not continuous, but originates from frequent streams, is readily grasped, since the waters of two wells barely six paces away from each other can differ a good deal in taste and healthiness. The streams are mostly conducted on a tortuous route, not a straight one, either because of the inflow of another one, or because of rocks in midstream, or because the waters have found some hollow into which they can more readily flow. So if you want to tunnel[34] under them, you can do it, as I said, in three ways, and can discover earths of various kinds, stones, metals, juices, and the remaining things of this kind.

But I return again to the use of earths. In Waldeburg in Germany there is a sort of potter's clay that is compact and fatty, and of very fine[35] substance, and resistant to fire; it does not absorb liquids nor exude them. Pottery vases appear to have the following five strong points:[36] they are very smooth, and non-absorbent, and do not ooze, and are not fragile, and are fire-resistant. It is remarkable how small a difference gives the Florentines the edge in food storage, because their pots are fire-resistant—the Milanese ones are not.[37] However, pottery is made everywhere, if someone knows the method[38] of making very good pottery from the earth which is in use for making pottery vessels for the liquefaction of metals. This earth is derived from stone with a metallic &341 content. Who could really suppose that the vessels that support the liquefaction of gold and silver are

[31] The tale is in Herodotus, *Histories* 1. 191. Cyrus wished to capture Babylon, and did so by diverting the river Euphrates from its course through the city; his army could then enter the city along the river bed. But his adviser on this is not named as Croesus or indeed at all; Cardano has confused this tale with one that follows shortly after in Herodotus.

[32] "non amplius reducentes."

[33] "aequalis."

[34] "fodere."

[35] "tenuissimae."

[36] "laudes."

[37] The following four sentences first appear in 1554.

[38] "ratio."

not good enough for cooking food? And so I have had made for me from such earth a cauldron to use, one that lasts practically for ever if not knocked; fire has no effect upon it. So it is clear that the potter's earth should be of open, indeed very open, texture, and by nature light and fatty. If this kind of earth is kneaded well and long, it creates vessels very close in quality to [436]agate[39] ones. Agate articles are what are nowadays called porcelain[40] articles; Pliny's word is that "the East sends vessels of agate; they are found there in several places, notable places, especially in the kingdom of Parthia, but chiefly in Carmania."[41] They suppose it is a humour, and compacted by heat below the earth. In size the vessels nowhere exceed small abacuses, and in thickness rarely exceed what is said to be required for a goblet.[42] They have brilliance without strength, and their glint is more genuine than their brilliance. What is prized is diversity of colours, with patches running round at intervals into purple and shiny white, and a third kind glowing from both, as when purple reddens or milk whitens through changeover of colour. There are people who lavish praise on the outlying instances in these, and some reflections[43] of colours like those seen in a bow in heaven.[44] These people appreciate fatty patches. It is a fault for an item to be translucent or be pale — so are salty grains and warts that do not protrude, but as in the case of the body are usually sessile. And there is some advantage in odour."[45] So is there anyone who

[39] The word translated here as agate in Nenci in this whole passage from here is "myrrhina"; Loeb says myrrhina means fluorspar, but *OLD* gives both indifferently, and derives the word from μούρρινος. See also n. 45 below.

[40] Although Marco Polo (ca. 1254–1324) has been said to have brought this word from China, much more plausible is the derivation from the French word "porcelaine," from Old French "pourcelaine," from Italian "porcellana," "of a sow," hence also meaning a cowry shell, from the resemblance of the cowry shell to the vulva of a sow; "porcellana" is itself derived from "porcella," diminutive of "porca," sow, from Latin, feminine of "porcus," swine.

[41] A country (modern Kirman) to the north of the Persian Gulf at its eastern end. Plin. *Nat. Hist.* 12. 56 (*OLD*) and 37. 21.

[42] "vas potorium."

[43] "repercussus."

[44] On rainbows, see Book IV, at 281 (1560) ff.

[45] Pliny (*Nat. Hist.* 37. 21–22) writes this of "myrrhina," not agate ("achates"). Eichholz (Loeb 10: 179–81) holds that "myrrhina" was probably fluorspar, and says this is still to be found in Kirman, the modern name of Carmania. His translation here runs: "It is in Carmania that the finest specimens exist. The substance is thought to be a liquid which is solidified underground by heat. In size the pieces are never larger than a small display stand ('abacus'), while in bulk they rarely equal the drinking vessels that we have discussed. They shine, but without intensity; indeed, it would be truer to say that they glisten rather than shine. Their value lies in their varied colours: the veins, as they revolve, repeatedly vary from purple to white or a mixture of the two, the purple becoming fiery or the milk-white becoming red as though the new colour were passing through the vein.

does not see that these are pottery, and of the sort that I said to-day we usually call porcelain?[46] They are made &342 from some juice compacted underground, and are imported from the East. But our own are paler, and free of odour, and those among them that are translucent are more esteemed, and attractive with leaves and pictures, and no trace of purple. All these features appear to deviate from the ancient agate, but the differences of time and of craftsmen and of uses have brought this about. High price creates supply, while people strive to increase production;[47] when more superior material ran short, they supplied some other; then colouring is devised to compensate for cheapness, and so the repute and honesty of a vessel has departed. Either the material is cheaper, or is not the same, or altogether less pure, or not very well worked, or the vessels themselves are extracted prematurely from the kiln by people greedy for gain and impatient of delay, whatever way the job and the price and the material and the method of manufacture work out, it tells us that these are the same as agate articles.[48] Nowadays they are made in a long region of India, and especially in China; the people there were once the "Seres,"[49] as has been remarked elsewhere. It is said that they are made from the shells of shellfish and of eggs, and are buried (according to a regular rumour) for eighty or a hundred years, as a substitute for inheritances. Then they are dug up, and covered with glass[50] to prevent

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Some people particularly appreciate the edges of a piece, where colours may be reflected such as we observe in the inner part of a rainbow. Others prefer thick veins (any trace of transparency or fading is always a fault) and also specks and spots. These spots do not protrude, but are usually flattened, like warts on the body. The smell of the substance is also a merit."

[46] See n. 40 above.

[47] "multitudinem augere."

[48] "eadem esse docet haec myrrhinis"; Nenci (434 n. 15) mentions that Cardano and Scaliger were denounced later for supposing, in ignorance of Pliny, that agate ("myrrhina," not "achates") was a source material for earthenware. The following seven sentences first appear in 1554.

[49] "The inhabitants of a region lying beyond Scythia and India, the Chinese or neighbouring peoples" (*OLD*).

[50] This word is reminiscent of the "waterglass" (sodium silicate) used within my memory as the best long-term way to preserve hens' eggs. A viscous transparent liquid, it permitted no atmospheric gases (oxygen especially) to pass, and so the eggs remained free of decay for some long time. On "hundred-year eggs": "Also called century egg, thousand-year egg and Ming Dynasty egg, all of which are eggs that have been preserved by being covered with a coating of lime, ashes and salt before being shallowly buried for 100 *days*. The lime 'petrifies' the egg, making it look like it's been buried for at least a century. The black outer coating and shell are removed to reveal a firm, amber-colored white and creamy, dark green yolk. The flavor is pungent and cheeselike. Eggs from chickens are generally used, though duck and goose eggs are also preserved in this manner.

them absorbing anything. The juices with which the shells are protected[51] are not sufficiently known. Also, they are painted before the glass is added. Because of their glint and hardness, it is uncertain whether they are thoroughly cooked. They cost more, but are much inferior to the ancient ones. And despite this, it is no less ostentatious[52] to feast on these than on gilded vessels made from silver,[53] whether because their scarcity and the work involved have recommended them, or because of an established rumour that they could not convey &343 poison. A further point: the greater distinction of Lemnian earth among the kinds of earths or potter's earths. Lemnos is an island in our sea;[54] the mountain that creates its earth lacks stones and trees, but the earth is nevertheless useful for bloody fluxes and ulcers, but more so for poisons.[55] Hence the earth does not support any tree, being very dry, and does not condense into stone, since it is of such rarefied substance that it does not absorb water, but rather is absorbed by water. It also possesses some fatness, through which it resists poisons.[56]

Since we can produce an earth of the kind by technical skill, what is clear from this is that if we grind up common potter's earth for a long time, and sprinkle it with water in which are garlic and uncooked juniper seed; shape it into heaps, then again grind it up, sprinkle it, and heap it up and dry it; this will require expenditure of time, and restore usefulness. For the price of Lemnian tablet[57] is comparable to that of gold, so hugely has this very cheap thing increased in price, when scarcity has stopped its being generally available. When it achieved the eager interest of the main physicians who attend the king of the East, it started to be reckoned more celebrated. Yet it has no odour, an uncommon thing in earths and in all waters. For them actually to smell good, rarefied and well-concocted moistness is needed. The moistness of water cannot be well concocted, because most of it is earth and is not rarefied. The odour, as I said, is not pleasant; but with some additives earth and water get to smell good. Hence it is clear that even if earth and water smell good, they quickly lose their smell, as happens to rose water, and &344 more so to violet water. The bulk of earth and water is odour-free; there is also a substantial part that smells heavily, and a very small one that smells good.

Hundred-year eggs are sold individually and can be found in Chinese markets." [http://allrecipes.com, accessed 22 May 2009]

51 "excipiuntur."

52 "superbum."

53 The remainder of this sentence first appears in 1560.

54 The Aegean Sea—the northeastern part of the Mediterranean ("our") Sea.

55 The syntax is distorted but the sense is clear.

56 On Lemnian earth, see n. 13 above.

57 "sphragis": a block of the earth marked with a seal to authenticate it.

Armenian earth is the nearest one to Lemnian[58]—it is more truly Samian earth than Armenian, being imported not from Armenia but from nearer, and it is not Lemnian. But it conforms exactly to Galen's description of Samian earth, since it is reddish[59] and an excellent drying agent; hence it is health-giving for pestilent diseases and for the wasting[60] that comes from lung ulcer.[61] Indeed, for the same reason carbuncles,[62] emeralds, sapphires, hyacinths,[63] pearls, and corals are of use in plague, evidently because they are powerfully drying. But while they do this less than Armenian clay,[64] these stones are of more use for restoring vital spirit. So Armenian clay is extremely dry, and moderately cold, minimally bitter, yet very rarefied. This renders it also of use against corroding poisons, such as cantharides, and against ones that produce decay, such as sea hare.[65]

There is also in Apulia a red clay, one not unlike Armenian earth in powers, but much weaker. But what prevents it being made even better than Armenian? Wash Apulian clay, clear it of sand, then carefully dry it with very acid vinegar and extract it with a sixth part of oil, so that it is reduced to the form of a porridge.[66] You will bury it in a moist[67] place for many years. Then on this plan you will create a preparation against poisonous medicaments as well as worms, by

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[58] The remainder of this sentence and the opening of the next one first appear in 1554.

[59] Scaliger (*Exercitatio* 94 [330]) complains that Galen wrote that Armenian earth was pale, not red—which Galen did (*De simplicium medicamentorum temperamentis et facultatibus*, 9; K. 12: 189: τὴν χρόαν ὠχρά).

[60] "tabes."

[61] Armenian earth was introduced by Galen in the form of a very dry clay, like lime; but a different product, with green and blue patches like lapis lazuli, was subsequently introduced; on this see Castelli, citing Mattioli, the Italian artist and botanist contemporary with Cardano, on whom see n. in Book II at 190 (1560). For references on Armenian earth, see Nenci, 436–37 n. 18.

[62] I.e. the precious stone.

[63] On hyacinths see n. to Book II at (1560).

[64] "lutum."

[65] A kind of sea slug, *Aplysia*, a fast-moving pteropod ("wing-foot"), so called because its foot is broadened laterally to form "wings." Using these the sea hare is able nearly to fly through the water. It is also mentioned by Jean Fernel, who says that the poison of the sea-hare ulcerates the lungs, citing Galen as his source; see Forrester and Henry, *Jean Fernel's On the Hidden Causes of Things*, 633, 645, 691. In Fernel's *Pathologia* (Bk. I, chap. 7) the effect is attributed to dissolution of the "Total Substance."

[66] "puls."

[67] The Latin is "hudo"; on interpreting this as an abbreviation for "humido" see n. in Book II at 226 (1560).

prolonged grinding up of the purest potter's earth, oil, vinegar, garlic, juniper seed, gentian, and "diptamo"[68] and then &345 burying it for many years.

Someone will perhaps enquire, what could such a long burial contribute to life? Evidently it is the same cause as the one leading to the generation of metals in the mountains. But it is livelier[69] in the mountains, for many reasons. Mountains have in fact a species of life, since they consist of rocks.[70] We will explain that rocks are alive: where there is life, there too all [437]natural generation proceeds more readily. In addition, the powers of mountains are not drained off by mattocks,[71] hoes, and the plough, and they are not forced to perspire[72] by human effort. The substance of mountains is more solid, too, so that their famous heat is better held in — the heat that in fields is dispersed because of the earth's softness. We have already explained that this heat is celestial—both because the fiery heat that is left[73] (and putrid heat is little different) is useless for generation at any point, and also because it is more in the East and on the Equator that we see the more esteemed gems and the most perfect gold being generated. Furthermore, anyone who compares gems of this same sort generated in the East and on the Equator, such as carbuncles and amethysts, with those that Germany exports, will observe that they differ remarkably in hardness and brilliance, and so powerfully that one would suppose they were not of the same kind. The reason is that the East is hotter and moister and fattier. So if these things are generated from seeds, the heat would either be fiery or putrid, and since even in Iceland in the North the mountains are on fire, what would stop the most perfect gems being generated, and gold being present in plenty?

&346 There are also snowfields in the mountains, and long-lasting ice, which conceal heat at their bottom, and therefore make everything cheerful when the heat is dispersed in the fields by the external heat of the air. To return to the topic of mountains: the result is that mountains are more available for the

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68 "Diptamum" appears again later in *De Subtilitate*, in Book VIII at 518 (1560). *OLD*, *L&S* and the *Lexicon Medicum* of Castelli do not include this word, which is pretty clearly a corruption of δίκταμνον, dittany of Crete, *Origanum dictamnus*, and this plant is often mentioned by Galen (see Durling, *Dictionary*, 131–32). The corrupt form used by Cardano appears in Nicholas Monardes (1512–1588), *Newes out of the Newe Found World* [no date given], who wrote of "a true Diptamo which groweth in the Iland of Crete . . . whereunto the people of the Isle doo runne, when they feele themselves hurte by any venomous hearbes."

69 "vivacior."

70 Scaliger (*Exercitatio* 98(2) [334]) here mocks Cardano by addressing the "soul of Mount Taurus, and that of the Pyrenees and our Alps."

71 "Ligonibus"—an agricultural implement for digging trenches.

72 "perspirare." While this word does not appear to have meant "perspire" in classical Latin, Castelli equates it with διαπνοή and explains that air enters through the skin's pores and emerges again laden with moisture.

73 "reliquus."

generation of metallics. And their power is not exhausted by trees or herbage either; mountains are more sterile than fields, even if they the mountains are very fertile. Water and moistness, too, run down more from the mountains because of the sloping location, and their abundance on the surface of fields impedes the generation of metals.

But you will say: "At one moment you have included among the causes for fields not generating metallics the removal of moistness—at another you consider contrariwise that the abundance of moistness there impedes the generation of metallics." And good heavens, both are true!—the more there is of fatty moistness, the more fertile the soil gets, not only of metals but also of plants; and wateriness is an obstacle. The reason for this is that moistness suits generation, but should be hot too. Wateriness is cold moistness, and a stubborn enemy of concoction. So the most fertile of all regions are the hot ones where water has been plentiful, since watery moistness changes rapidly into fatty moistness with the Sun's heat; but in cold regions a lot of water leads to sterility and chills the fields.

Things are almost the same with the seasons. Meadows do rejoice with the waters in summer; in winter diligent watering makes herbage sprout more slowly, and thus it is accepted that &347 in comparison with mountains, fields have more of the watery moistness, and less of the fatty. And so you will notice that mountains productive of trees and vines hardly abound with metallics, unless deep down, because the fatty moistness is abstracted by the plants. But where the stones are very large and solid, the moistness is held by the rocks for a long time, and by distilling off the most rarefied portion condenses into valuable gems. And this is why the more brilliant gems are usually discovered among the hardest and largest rocks. A feature additional to the numerous advantages of mountains for the generation of metallics is that where you have dug down into mountains for two or three hundred yards, you could say you were still above ground level, and thus could channel and convey away water from the side and the earth now extracted. On the level, this work is entirely doubled: the place cannot be opened up by landslides,[74] as in the mountains, nor can you easily guess where the metallics are lying, nor can you follow up your finds as you do on a lofty site, since you can get no help from clues at the sides.

For these numerous and considerable reasons, few people devote attention to level places, even if there are metallics everywhere; most people set about mining the mountains. For one task is to discover the location and kind of the metal—a second and much greater one is to recognise the shaft for the mine.[75] To have discovered it only from a loftier spot is very laborious. To go over the point again in more detail: since, as I said, streams of water run everywhere underground, and again, there is also earth under the water, in which there are usually metallics

[74] "ruinis."

[75] "truncum fodinae."

lying in the levels, again most people think there is water underground, so that some of them have believed there are sweet waters &348 below the bottom of the sea, though this is difficult to test—as I hear elsewhere, at Venice they tried in vain (but without persistent enquiry)[76] to find out whether there is another layer of water below the first one. Evidence of this seems to me to be that even in the depths of the human body there are veins. And people relate that the river Arethusa, coming from Elis under the name "Alpheus," emerges in Sicily near Syracuse after crossing the sea. There are people who call Arethusa a spring rather than a river.[77] Also, sweet water on islands can make this point. Finally, since we see water on mountain ridges and then emerging at the bottom, what else can we conjecture about earth? Whether a mountain is buried in earth or protrudes, the explanation is the same, and this line of thought serves as evidence. I am not properly aware what stopped the finding of sweet water at Venice.[78]

But there are people too who draw a quantity of sweet water from the sea, on Aristotle's authority,[79] and on genuine experience. In fact a small vessel of wax, quite thick and sealed all round, is lowered down, and when it has remained a long time in the sea, it lets water in, but not salt—thus sweet water fit to drink is extracted; water, being rarefied, enters—salt, being earthy, is excluded by the

[76] "nondum constante quaesito."

[77] This tale is briefly hinted at in Pindar (*Nemea,* 1. 1). The version in Ovid (*Metamorphoses,* 5. 599, and at greater length in *Fasti,* 4. 423) is more romantic: Arethusa was a nymph who was pursued by the river-god Alpheus (Alpheus being the largest river of the Peloponnese) and passed under the sea to emerge as a spring near Syracuse. Pliny (*Nat. Hist.* 2. 225; Loeb 1: 353) runs: "But some rivers so hate the sea that they actually flow underneath the bottom of it; for instance the spring Arethusa at Syracuse, in which things emerge which have been thrown into the Alpheus which flows through Olympia and reaches the coast in the Peloponnese." And again (*Nat. Hist.* 31. 55; Loeb 8: 413) and still more remarkable: "The following phenomena too are very wonderful: the Arethusa at Syracuse smells of dung during the Olympic games, a likely thing, for the Alpheus crosses to that island [Sicily] under the bed of the seas." Strabo too (*Geographia,* 6. 2. 4) mentions the finding of a goblet at the fountain which had been thrown in at Olympia, and staining of the fountain's water by sacrificial blood shed at Olympia; but he is highly sceptical. See Brumble, *Myths,* 19.

[78] Scaliger (*Exercitatio* 100(3) [344–45]) accepts that Venice has no freshwater wells, but contends that it could have, by following a procedure he outlines of lining dug wells and extracting the contents repeatedly.

[79] Aristotle, *Meteorologica,* 2. 3, 358b34–359a5; Loeb 157–9: "That saltness consists in an admixture is evident not only from what has now been said but also from the following experiment. Make a jar of wax and put it into the sea, having fastened its mouth in such a way as to prevent the sea getting in. It will be found that the water which gets through the wax walls is fresh, for the earthy substance whose admixture caused the saltness is separated off as though by a filter." Aristotle repeats this in his *Historia Animalium* (7 [8]. 2. 2, 590a21–26; Loeb 11: 81–2.).

wax.[80] People say something has been found that attracts salt as if from a clot of rather fatty milk, to the great benefit of ships, if it is true, since it enables sweet water to be made anywhere from salty water. It is not very remarkable either that salt should be attracted or coerced, since attraction in milk, as we will explain, is done not by a property but by heat. &349 So sweet water is made from salty by as many methods as can clear water of salt. There are three possible methods: by its descending, by its being coerced, and by its being strained off. Possibly a fourth method too may possibly be discovered, if the sharp power of salt is blunted. Perhaps it can be done with a small amount, but not in bulk. We have mentioned elsewhere now how it can percolate: a long period of rest causes it to make for the bottom, but before it decays; what is left, then, is for us to [438]explain how it is coerced. This is done by heat, not a dispersing heat but an attracting heat. We will explain lower down.

And so to get back to my plan: the first mixing takes place in earth under water, and as I said, the generation of various mixed things occurs mostly in mountains. Mixture is properly mentioned here; it occurs in four ways. One is mixture of unlike things and of those that change their form — this is called generation, which we will discuss here. Another is mixture of unlike things, and they do not all change their form — if it is of liquids, it is called crasis, as when water and wine are being mixed, but if of dry things, it is called mixture, as when millet and wheat and oats are combined together. And if they are alike things, it will be called a heap — and this is a fourth kind of mixture, as occurs when cereal is gathered together into a pile.

Before speaking about complete mixture, I am going to discuss crasis, as more obvious to the senses. We said that wine mixed with water is being mixed through crasis;[81] since neither substance passes away, the form of the wine &350 is still there.[82] And thus, to prevent the mutual invasion of the bodies or their division into minima, so that bodies would consist of the individual particles, the form had to be increased, but not the matter, as Aristotle rightly holds in

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[80] The remainder of this paragraph first appears in 1554.

[81] It is a curiosity of language that in modern Greek the classical word for wine (οἶνος) has been displaced by the very word used here for the *mixture* (κρασί). This was so by Cardano's time: Scaliger (*Exercitatio* 101[10] [355]) remarks that in Greece the "plebs" use this latter word for wine, and also that the ancient word for the *mixture* of water and wine was κρᾶμα. For discussion of crasis and mixture see also Book II at 137 (1560) and n. there.

[82] On the complex debate, especially during the thirteenth and fourteenth centuries, about mixture, and about "minima" in contrast to atoms, see Maier, *Die Struktur der materiellen Substanz*, and Emerton, *Scientific Reinterpretation of Form*, chap. 3; also R. Wood and M. Weisberg, "Interpreting Aristotle on Mixture," *Studies in the History and Philosophy of Science* 35 (2004): 681–706.

connection with increase.[83] For when something is added to a tiny thing, it is impossible for the whole to be mixed; if the bodily forms are mingled, the bodies would penetrate each other. But we can see the form of the wine everywhere in wine mixed with water, even if the wine's body is not everywhere—it happened like this in true mixture—for, as I said, water is not really mixed with wine.

In the case of things that are really mixed, all the forms have to pass away, at any rate in part. But the form of the wine does not pass away at all. Experience shows that water does not get perfectly mixed with wine. And if a piece of linen is placed on wine mixed with water, and sticks out of the pitcher, the water rises up through the linen out of the whole vessel, and leaves the wine pure in the wine-cup. In this experiment the diluent emerges from the pure wine,[84] which could not occur if the wine and water were mixed. Again, water makes for the bottom of a wine-cup, and so a drink is tasteless at the bottom; also, it is far better to pour wine onto water than water onto wine. But if you put wine gradually onto water, it will float on top, not just according to the experiment mentioned, but because if you put a crust of bread first on the water and then pour wine gradually onto the crust, you will see (and clearly too) that when you take off the crust, the wine is floating on the water, without any mixture having started. So these three components can be seen separately in a wine-cup: wine under oil, and water under wine.

&351 Thus it is a fair question which of these is the more rarefied. On the basis of position, if what is lighter floats,[85] oil is lighter than wine, and wine than water. The fact that oil readily takes fire, and water never, is convincing that wine is intermediate. Furthermore, wine is a ninth part heavier than oil, on Galen's evidence, for when you have poured out the oil from a vessel that held nine pounds of it and filled it with wine, the wine's weight will amount to ten pounds.[86] And so nothing is more conducive to long life than oil, because it is very rarefied, very fatty, and devoid of residues. The result is that it greatly kindles the natural heat, because of its fattiness and rarefied state.[87] Through its purity, it wearies the actual heat very little, and does not block the pathways. These two hindrances may do a lot to shorten life. So mead would be good, although one might use oil.[88] In fact the best thing of all is to produce no residues—and next to that, to expel instantly those that have been produced. To

[83] The Aristotelian passage is *De generatione et corruptione*, 1. 5, 322a25–33 (ed. M. Rashed [Paris: Les Belles Lettres, 2005]) and as Rashed remarks, is "incompréhensible" as it stands. For interpretation see that edition, 126–29.

[84] "proditur dilutum à puro."

[85] "superstat."

[86] This test is reported in a very short tabular work once attributed to Galen (pseudo-Galen, *De ponderibus et mensuris*, K. 19: 748).

[87] "tenuitas."

[88] "Valeat igitur mulsum, cùm oleo uti licuerit."

have held back residues does so much damage that retained urine regularly gives rise to a stone—hence people given to entertainment,[89] reading and writing are easily seized by this kind of disease. Failing to expel excesses sometimes leads to immediate death. So oil is conducive to life in so many ways.

A fourth piece of evidence of the rarefied state of oil is that it penetrates easily. It is put on locks for this reason, so that the keys turn easily. Contrariwise, saltpetre mixed with melted wax prevents leggings[90] from letting water through at all, if they are &352 permeated with it in front of a fire for a long time; the salpetre needs to be very finely ground. And if you have mixed something fatty with the wax, it will be still better.

But I return to my planned debate. Three approaches in fact show that water is more rarefied than oil and wine. First, that if water and oil are mixed and placed in a vessel on a fire, all the water is evaporated before barely a drop of oil, although the water is more resistant[91] through its coldness, and takes up less heat as it lies at the bottom, the vessel being cold there, and can with some difficulty steam off,[92] because the oil confines it, even if it is turned into vapour.

Secondly, that when someone has drunk water in summer, it comes out immediately as sweat, but oil and wine do not. Thirdly, because water is more transparent than both the others. But the reason for the transparency is that it lacks colour: the reason for the speedy resolution is that it is minimally fatty; the reason for the sweat is that it is not nourishing, and also that through cold the hotness already dispersed expels the humour outside—and it does not emerge itself, but only expels the boiling serous part of the humour.

But you will say that Aristotle's view is that water is more rarefied than oil.[93] But by "rarefied" he meant thin[94] and minimally sticky, or also, not condensed. He would perhaps give precedence to wine over water, because it floats on top—but that does not prove it. The fattiness does float on water,[95] since it is condensed, and does not move downward, because it is clinging, which a thin layer of lead is not. Things that are actually fatty do not sink, even if they were heavier, not just because they contain air, but also because they cannot help going

[89] "ludus."

[90] "ocreae."

[91] "magis repugnet."

[92] "nec vix possit exhalare . . . ." The combination of "nec" ("and not") and "vix" ("hardly," or "with difficulty") is confusing, but since in fact the water must escape first, with or without "difficulty," since it has a lower boiling point than the oil, I have translated as shown.

[93] "Water is the thinnest (λεπτότατον) of all liquids, thinner even than oil, though oil on the other hand spreads out more than water, on account of its viscosity." (Aristotle, *De sensu et sensibilibus*, 4. 441a25–27; Loeb 235).

[94] "rarum."

[95] "superstat."

down all together. Whey[96] is much more rarefied than &353 any of these; if it boils, it boils away very fast; hence much more is usually added in decoctions; or it is particularly suited for items that require brief cooking. So since such things can barely mix, they will never create a crasis.

On the same basis, milk is not mixed with wine either. People generally move wine that has gone bad into a clean vessel, and [439]gradually add a tenth part of milk; then after a week they open the vessel and sell the contents little by little, provided it looks clear and good. But if it stays longer in the wine-cup or vessel, it goes bad over again. Also, what got spilled on the edge of the wine-cup leaves behind a buttery fattiness, which reveals the swindle. However, it is a lucrative swindle. But if prevention is more the plan, then before the wine is disturbed to stop it decaying, a tenth part of alcohol mixed in produces the result; far better is sulphur, but it gives away the trick by its smell; I remember drinking some. Alum can do the same, but both are dangerous and violently impair health.[97] To sum up: everything heavy or viscous[98] clears wine—sticky things such as milk and white of egg—which is why all liquors are purefied by its addition. Heavy things work while making for the bottom—heavy things such as river pebbles heated till they crack and then reduced to powder. Being in fact mixed and dry, they attract anything like clay—that is what turbulence comes from. When they have done their attracting, they move down to the bottom in the wine and purefy it. Salt will therefore be capable of the same result, but reveals the swindle by its taste, and makes the wine unpleasing.[99] &354 It is easy, too, to detect all wines adulterated by metallics. Leave them in the wine-cup for twenty-four hours while the metallic makes for the bottom because of its weight, and the wines grow flat and lose their remaining colour.[100] But if the wine is adulterated with honey, this is revealed at once by sprinkling a few drops on red-hot[101] iron; as the wine is evaporated, the honey remains.[102] Since the substance of the wine is more rarefied than that of honey, as the former evaporates the latter remains.

Similarly, if honey is adulterated (which is usually done with millet flour), when it is boiled down, the foam removed and the honey put in a glass vessel, it stays cloudy in its upper part. In this way I had the opportunity during the past

[96] This sentence first appears in 1560.

[97] The following five sentences first appear in 1554.

[98] "lentus."

[99] Nenci (447 n. 33) cites a description of similar methods of "purifying" wine in a work published in Augsburg in 1421.

[100] The remainder of this paragraph together with the next one first appear in 1554.

[101] "candens."

[102] Cardano does not mention the caramel smell which might be expected to develop in these circumstances!

year to unmask the ointment[103] of a merchant at Pavia. And if it is adulterated with some heavier powder, what is added settles downward, and so it is dim at the bottom. Olive oil betrays deceit when taking fire; either it crackles, or it whistles, or more of its watery fluid[104] is gathered than corresponds to the amount of oil.

Why then does milk improve wine? It is because with a sort of crasis being created, the fat settles, carrying with it the turbid part of the milk and leaving the watery part in the wine—the part that conceals the defects of the wine. Then small portions of the wine reveal the defects, because through their weakness they are more rapidly turned bad again by the air. But cloves fastened all round to a Seville orange,[105] which is hung in the vessel without touching the wine, also convert a defect of odour into an attraction. Therefore things not alike by nature do not make a crasis, such as wine with water, unless a weak one—much less still does wine with milk, and these liquids do not make one at all with oil. But lora[106] is more genuinely mixed, because it has boiled up.[107] &355 But it is not clearly mixed, since mixture is the work of nature, not of art, nor even of fire. So everything that is genuinely mixed displays only one form of an element, but not precisely: only the powers of the others. If in a mixture the elements were not present everywhere, what is mixed would be a heap, not a generated thing; if they are everywhere and in relation to substance, the bodies would interpenetrate each other. This is made clear in works on medicine.[108] So the form of a mixed victorious element is imperfect.[109] And it is acquired gradually—a circumstance obvious in the case of elements, and Melanchthon considers that it occurs in the case of the others too.[110] This appears sufficiently compatible with reason,

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103 "Seplasia." Originally this word meant a street in the town of Capua where unguents etc. were sold (*OLD*), and "seplasium" meant the ointment made or sold there. Its adulteration was notorious even in Cicero's time (for references see *OLD*). Cardano appears here to use the classical word for the street to mean the ointment, or possibly the swindle.

104 "Amurca": this is a watery fluid contained in olives in addition to the oil and the solid residues (*OLD*).

105 "citrangulum"—see n. to Book II at 158 [1560].

106 A drink made from watered grapeskins (*OLD*).

107 "efferbuerit"—there is some confusion here between "b" and "u/v," owing to pronunciation, since "efferuerit" is the classical grammatical form.

108 A marginal here ("2 Contradic. tract. 1, contr. 1") is correct. Cardano's treatise *Contradicentia medica* (see n. to Book II at 158 (1560) above) has a section in its Book II, *Tractatus primus, contradictio I*, entitled "Forma mixti an sit ex elementis, an elementis praedominantis, an alia addita?" and this appears in *OO* 6: 437–40, and particularly addresses medical problems related to mixtures.

109 The following five sentences first appear in 1554.

110 In his *Initia doctrinae physicae* (in *Opera omnia*, ed. Bretschneider, vol. 13, cited here by Nenci). The cited passage reads ". . . corrupta priore forma," not "priora" with Nenci. But there no clear indication is given of the *gradual* acquisition of a form, nor of

since the form is that of the dominant element, but is gradually lost, and indeed gradually acquired. In some of the more notable instances, Aristotle believes it is not acquired entirely gradually, but stepwise:[111] after a fetus first comes alive in the womb, next it feels, and afterwards it becomes possessed of a mind. The soul, in which is the mind, is completed later. The mind arrives externally, and it is closer to the senses. All mixed things are either earthy (like stones and plants) or watery (like milk and oil) or wholly mixed (like the bodies of animals). So mixture does not proceed in the way that nutrition or growth do—in mixture, something is added to something else; in such cases,[112] what is in potentiality is added to what is in actuality, and growth goes on according to some part of the form, but not part of matter, because matter is capable of unlimited division. And the same applies to nutrition. So growth and nutrition are truly in accord with the form, and only addition is &356 in accord with the matter, since all round something gets added on. Thus when nutriment is added, a very small portion of the flesh is wholly increased in accord with the form, but not in accord with the matter—in fact only in roundabout fashion.[113] Yet not properly in this way; in fact, as I said, the basis of growth and nutrition—and indeed of generation—is almost the same; these processes take place from the soul. In fact it is a task for the soul alone to be capable in this fashion of thinning out and then uniting and transmuting. If indeed there is anything devoid of life that could do this, it would above all be fire—the toughest of all the lifeless things—yet it cannot. As indeed we have already explained, what is added is placed beside what is being burnt up, but does not enter the earlier substance. And so all mixed things must be alive or have been so.

Let an explanation be derived in this fashion: because they[114] are nourished, and nourishing does not take place except by the soul, and what possesses a soul is alive. But if you deny that they are nourished, you will anyway accept that they are generated; yet nothing is generated except by a soul, because, as I said, it alone does mixing. We also see that all mixed things gradually decline from the heavier elements, as stones do, and metallic earths rather less, but juices more so, then metals, plants later on, and the imperfect animals, and then the more perfect ones gradually till we get to the human being, whose composition appears so far removed from the nature and substance of the elements that there is no way that any one could think him built up from them. So if the human being, the

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what these "others" are that differ from elements. Melanchthon wrote: "Nec generatio unius elementi ex uno elemento est mixtio; sed cum plura elementa iuncta gignunt novam et mixtam substantiam." And he does insist here that in a mixture all four elements must be present.

111 "per gradus."

112 "in illis"—the bodies of animals, presumably.

113 "in circuitu"—or possibly the meaning is, "in cyclic fashion."

114 Mixed things, presumably.

animals, and the plants are alive, then &357 since the celestial heat that mixes all these things is one and the same (but more in one case and less in another, as we will demonstrate at the appropriate point), it is clear that, as Hippocrates[115] correctly said, the soul is nothing other than that famous celestial heat.[116] This complies with Aristotle's view, when he wishes the heat of spirit to possess some relation to the element of the [440]stars.[117] For whether heat is the soul, or the soul's primary instrument, where heat appears the soul evidently ought to be present as well, hence life too—indeed, life is nothing but what the soul does.[118]

This would be clearer from experience: when lead is turned into white lead,[119] and burned, its weight is increased by one thirteenth part. The reason is that the celestial heat vanishes away—certainly nothing is added, and yet the weight increases. A comparable situation turns up in animals, which get heavier on death, because on the soul's being breathed forth, with it departs the heat too and anything it has developed—so it is clear that metallic bodies and stones themselves are still alive.

But you will say: when a lighter portion, in fact the heat, has been removed from animals or metallics, how can what is left get heavier? This clearly does occur, as in the case of glass eggs which float on water. In addition, with steel and

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[115] Physician of the island of Cos in the Aegean Sea in the fifth century B.C., whose name is attached to a substantial corpus of early Greek medical works. Although none can now be confidently attributed to him (*OCD*), in the time of Cardano and until the end of the 18th century, his authorship of the corpus was undisputed.

[116] Hippocrates (*De carnibus*, II; Loeb 8: 133) wrote: "I believe that what we call heat is in fact immortal, that it perceives all things, and sees, hears and knows all that is and all that will be." He does not there employ the word "soul," and indeed in another possibly Hippocratic treatise (Περὶ ἑβδομάδων 13) maintains that the soul is a mix of hot and cold.

[117] Aristotle, *De generatione animalium*, 2. 3, 736b30–37 (Loeb 171): "Now as far as we can see, the faculty of Soul of every kind has to do with some physical substance which is different from the so-called 'elements' and more divine than they are; and as the varieties of Soul differ from one another in the scale of value, so do the various substances concerned with them differ in their nature. In all cases the semen contains within itself that which causes it to be fertile—what is known as 'hot' substance, which is not fire or any similar substance, but the *pneuma* . . ."

[118] "est enim vita nihil aliud, quàm opus animae."

[119] "Cerussa," carbonate of lead ($2PbCO_3 . Pb(OH)_2$). It is a common mineral, still known as *cerussite*. But being a useful pigment, it was commonly produced from the metal. The theoretical weight change deducible from the formula is much greater than Cardano mentions here, being an increase close to one quarter, but there are many intermediates in the conversion (Taylor, *Chemistry*, 475), which could lead to diverse outcomes. Cardano could not of course be aware of oxygen, which is incorporated with the lead in the process. Note however that for Cardano (as Nenci observes in Book VI, 537 n. 1) "white lead" is commonly *tin* and "black lead" is lead.

lead ones, when the air contained inside them holds them up, but when they are broken they move down at once. It is not the air in us; but as the air in them holds them up in water, so in animals and metals the fiery part in air removes weight. Some substances of the elements are actually present &358 in mixed things, as I said, but they are broken; and also present are the qualities of other things, as there is watery substance in milk, and air and earth and an ethereal or fiery element concocted by heat in accord with its quality. Elements are present in mixed things in two modes: one is in virtue of generation, and only earth and water are present in that mode; but of one of these according to substance—the substance of the other one is not in evidence;[120] as the celestial heat acted in it, more items are in evidence as much in substance as in nature. This is how some compact things can be light and some rarefied things can be heavy; when a small amount of earth gets warm, as it passes over into the substance of air without the entry of air, it is light and compact, like all fatty stuff, and aloe wood. But on the other hand, if earth is worked too little, but there is a large portion of air inside and visible everywhere (though in very small particles), it will be described as rarefied, and yet be quite heavy. We readily understand a heavy thing being compact and a rarefied one being light.

From this the answer to a weighty question emerges: why it is that lead is heavier than earth; there is practically no rarefaction in lead, but when earth is not sticking together, it lets air in, and hence appears lighter than lead, because it contains water instead of air. In addition, this earth is not pure earth, but has an admixture of metallic substance. Another result is what people vouch for in connection with ashes: that a vessel full of them absorbs such a large amount of water without any ashes being expelled; plainly a significant portion of air needs to be present, and then there is puffing out of the more rarefied ash, but the remainder of it solidifies and is compacted, and a part of the water is freed by heat.[121] &359 As air is actually hotter than water, because it picks up more illumination on account of its rarefaction, air-containing dry things will be hotter than liquids. So when these undergo mixing, the thinner part of the moistness has to be turned into vapour. Hence if it is watery, it breathes forth moistness; if

[120] "non apparet."

[121] Cardano is evidently drawing here on Pseudo-Aristotle (*Problemata*, 25. 8, 938b24–34; Loeb 2: 61), cited here by Nenci, which runs: "Similar to this is the fact that the same vessel can contain as much ashes and water together as it can of each when poured in separately. For there seem to be many empty spaces in ashes. Hence the water, being lighter, sinks into them and fills them up completely, so that the mass grows dense, and because the filling has taken place with each of the parts (for everything which is filled by degrees becomes more full than if it is done all at once), when this happens the ashes subside; at the same time the ashes admit the liquid because they have interstices. But ashes which are cast into the water when hot, cleave the water and introduce air." The remainder of this paragraph first appears in 1560.

it is fatty, it swells. This is how people make things mixed from honey or sugar pour out from medicine containers,[122] to the astonishment of druggists;[123] the vapour cannot in fact make its way out, and the actual moistness causes the distension. And so this makes water mixed with powders reduce in size, but oil is seen to increase.

And so, to return to my plan, we gather that metallic things are alive from this piece of evidence[124] too, that in the mountains they are born like plants: with leaves indeed spread out, with roots, trunks, and as it were flowers and fruits, so that a metal or metallic substance is no different from a buried plant, and one coming to birth wholly underground. It was not capable of growth above the earth's surface either, because it was crumbly, like copperas,[125] or else too heavy, like lead. Thus among the animals we see the mole, and worms, and toads being born underground. But it was not appropriate for as many animals to be born underground as plants, because life and nutriment (all that metals need) can be created and completed underground; but respiration, by which the perfect animals can be created and completed, goes on there with some difficulty. This is why nature has begotten the kinds of metallics underground — many more kinds too than anyone supposes, so that I dare say they are beyond counting. If indeed nature embellishes the globe with more than five hundred species of herbs, and has introduced animals above them, it is likely that she has indulged herself[126] underground in as many ways, indeed in &360 far more ways, but many are unseen in the depths; others we transfer to the nearest kinds from the resemblance of colours or substance. Some are rare, so that they could hardly be found even if they were above ground — like quite a number of plants in our own time, but Dioscorides recalled these. Others too started to be disregarded after being found, through ignorance of their usefulness; this is why we know very few out of the huge number of metallics. Also, the kinds that we recognise are fewer than we suppose, because some are the fruits, leaves, exhalations, or roots of others, and those are the ones that are never detached; we will discuss what they are and their links[127] in their proper places. Now let us pursue our intended topic.

We had said that metallics and metals and also stones are alive. In fact items that possess ripeness and sourness and old age possess life too; some stones are found that are unripe, and of washed-out colour, and unconcocted substance; and in the same tree's fruits a purer and a less pure portion is visible. Furthermore, veins and the apparatus[128] of nutrition are present, and passages that are

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[122] "pyxides."

[123] "pharmacopolae."

[124] "argumentum."

[125] "calchantum"; see n. to Book II at 131 (1560).

[126] "lusisse."

[127] "quae sint, et quorum."

[128] "instrumenta."

not very roomy[129] but are softer, as can be seen in stones; thus we can readily be persuaded that they are nourished just like the plants and like animal bones; if indeed they grew by accession and addition, they would have no need of these at all. The stones that grow through heat alone, which we call tufa, and those that grow through cold alone have no veins and organised substance such as are present in true stones and those that have life; tufa is devoid of life. &361 There is death in them too, hence life as well. In my hands, the Herculean stone[130] has quite often actually become powerless[131] in a few years; although it used to attract iron with vigour, later as time passed it stopped doing so. What else is life really than the activity[132] of the soul? The point has been established in medical discourses that only living things possess activity. Even elements are alive in some fashion, as has been mentioned, since they proceed of themselves to their own regions, but all mixed things do so through a much better life—nature always aims at something better than what it sprang from. This is why I would not have believed Simplicius when he said that just as iron is attracted by a lodestone, he thought that gold was attracted by a bone of the gurnard fish.[133] He wrote this in his *Commentaries on the Physics*,[134] and it is at variance with reason, since that special bone is not alive. It has been shown that all activity is of some living thing, and to the extent that it is alive.[135] For even if the elements too are alive, this cannot be the work of the elements, but the attracting is the work of some particular thing.[136] Life is the feature of a living thing, and does at least make use of nutriment; but when you have detached it from the animal, a fish's bone is not alive with the kind of life that makes use of nutriment. With the soul removed it is clearly a sentient thing, but is the same as a nurse. And so I place such trust in this argument[137] that although no expert, I would dare to say that it is impossible for the bone of the gurnard fish to attract gold in the way that lodestone attracts iron; but undoubtedly this can be done by some other living thing, such as a stone or an animal or a tree, so long as it survives.[138]

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129 "laxiores."

130 Lodestone.

131 "extinctus est."

132 "operatio."

133 "miluus."

134 See *Simplicius on Aristotle's Physics* 8. 6–10; 1345. 31–32: "Also the bone of the hierax fish is said to attract gold, and this too may impart the same power to what it attracts proximately." That is, this bone may transfer magnetic power to some other item it attracts. It is not clear what bone is meant, and even D'Arcy Thompson (*Glossary of Greek Fishes*) does not report this tale.

135 "et ut vivit."

136 That is, the work of a soul. See n. to Book I, at 15 (1560).

137 "demonstratio."

138 The following two paragraphs first appear in 1554.

Suppose someone objects that the spine of a sting ray takes away &362[wrongly numbered 361] toothache if the gum is scraped with it.[139] Our reply is that this power, present in it in potentiality, not in actuality, resembles the ulcerating power of cantharides, in being brought into actuality by a faculty of the human soul. Then this spine inflicts severe pain — pain overshadows pain, provided it was not in the same part, as Hippocrates puts it, so much so that sharp gum pain blunts toothache.[140] It also, being nearby, summons away the cause of the pain, which is mostly in a nerve within the tooth — this neither happens always nor to everyone. And so since powers belong to living things only in actuality,[141] there must be a soul in stones that possess powers.

But you will say: "However, the Philosopher denies this."[142] But people who accept that stones are generated or grow should also agree that they are alive; the common features of the vegetative faculty are, on Galen's authority, to be generated, to be nourished, and to grow.[143] Nature also seems to proceed gradually from extreme to extreme, and to link by intermediaries things quite widely separated — for instance, an intermediary could be set up between something not nourished nor alive and something alive and nourished — an intermediary that would be alive and not be nourished, and that would be nourished and not be alive; but nothing could fail to be alive and fail to be nourished, since that would be a faculty without a subject and a principle. So the required intermediary needed rather to be something not being nourished —yet alive. A principle without a faculty does occur in things that are damaged by nature — so stones will be like that.

Then metallics lie in the mountains as trees do, with their roots, trunk, branches, numerous leaves, and some parts are slender, sometimes with flowers

[139] The "sacrificetur" of 1560 replaced the obviously correct "scarificetur" of 1550 and 1554. Nenci cites Pliny, *Nat. Hist.* 32. 79 (which refers to "draco marinus" as the fish that helps toothache) while elsewhere (9. 155) Pliny refers to the dire damage the sting of the sting ray ("pastinaca") can in general (not as applied to the gums) inflict. Celsus (*De medicina*, 6. 9) mentions this as an expedient to loosen painful teeth, towards the end of a long catalogue of remedies for toothache; the Loeb translation (2: 251) runs: "Also the tail spine of the flat fish which we call pastinace, and the Greeks trygon, is roasted, pounded and taken up in resin, and this, when applied around the tooth, loosens it."

[140] *Aphorisms*, 2. 46: "If a patient be subject to two pains arising in different parts of the body simultaneously, the stronger blunts the other."

[141] "in actuality only to living things" would be much more appropriate, but Cardano wrote, "vires viventibus cùm tantùm actu sint."

[142] Nenci cites Aristotle, *Magna moralia*, 1. 4, 1185a9–23; however, in this passage (1185a18–19) Aristotle denies to minerals only the *nutritive* soul.

[143] Galen (*On the Natural Faculties*, 1. 1 and 4) somewhat confusingly refers these three functions (functions present in both plants and animals) to Nature, rather than to the "vegetative faculty," and distinguishes Nature from Soul, the latter being confined to creatures possessing the powers of sensation and voluntary movement.

and fruits. &363 In fact most lack fruits and flowers, a feature we see present in plants too that come to life in wells and in shade, or in an excessively dry place, such as maidenhair fern, scolopendron,[144] lichen, and a number of wild figs, when they grow in walls; evidently fruit and flowers are evidence of a flourishing and fertile tree. Fertility originates from both the humour and the heat of the Sun. So this explains how it is not remarkable that metallics often lack flowers and fruit, since the Sun is always absent and plentiful humour is usually so too.

If you want to find where metallics are really plentiful, you need reliable and numerous guesses.[145] A fertile district is the first clue, as at present Germany is for silver. Similarly, in Italy silver can be mined with difficulty, gold not at all. And so there is a larger number of fertile fields in a fertile region—similarly, in a district rich in metals, most of the mountains yield metals even in defiance of expectation. Also, the harder the highest mountains are to mine, the more generous they are in production; it is uncommon to find this material in generous supply in the lower hills. Usually mountain summits that slope to the Equator, with roots facing north, promise metal, and especially silver, of which the more productive mines generally incline straight from East to West. Again, mountains in hot regions are more productive of gems, because on the Equator humour gets more dried and rarefied, and hence stones are generated by the dryness, but gemstones by the rarefaction, and metals are made by plentiful thick &364 humour. This thrives towards the North.

Furthermore, barren mountains are all metallic, for two reasons: the humour is used up internally, so that plants cannot be generated, and as well, the evil vapours[146] kill off even the plants already in being. Again, the colour of the mountains and stones and earth not only reveals that metallics are present but also of what sort: green is from copper, black from silver and gold, purple from pyrites, slate-coloured from lead and iron, sallow[147] from copperas[148] and juices of that sort, ash-coloured and dusky from sulphur. Odour is revealing too: when you have ground up two stones from the same mountain, if metal lies under the mountain, they give quite a smell of sulphur. This explains the erroneous belief that metals consist of sulphur, since there is this smell of metallic refuse[149] and an indication of excessive coction. Stones or earth too that are heavier than reason

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[144] Various mentions in Pliny indicate that for him this was a venomous centipede, and if marine, a nereid worm (*OLD*); it is also mentioned in the *De abditis rerum causis* of Jean Fernel; see Forrester and Henry, *Jean Fernel's On the Hidden Causes of Things*, 611. But surely here a plant is meant: hart's tongue, σκολόπενδρον, *Scolopendrium officinale* (Durling, *Dictionary*, 293).

[145] "coniecturae."

[146] "halitus."

[147] "luridus."

[148] "calchantum"; see n. to Book II at 131 (1560).

[149] "excrementum."

demands are reliable evidence of metallic material. If they are also too bright at some part, or being solid lack all brightness, you may be sure that there is metallic material underneath. Finally, if you arrange melting by fire, you will discover simultaneously that there is metal, and of what kind, and in what quantity. The waters running off also offer some slight guess at this, and if they display a foreign odour or colour, you will announce that there is undoubtedly metal in a mountain. You will also carefully inspect the bed of the trough, for you will come upon a part of the metal—a trace of metal can hardly &365 fail to appear, through the settling of the heavier part, each day always adding something with the long passage of time. A mountain also gets fissured because of the corrosive vapours of the metallics.

There are plants too that enjoy the company of metals, and as they are quite scarce, their presence provides quite convincing [442]evidence of metals. As a rule they are the kind that do not produce fruit, or not much: stunted juniper, ivy, wild fig, maritime pine,[150] and most of the prickly plants. The leaves of the trees are either pale or deciduous, and the trunks are thin, and everything is drooping. No wonder, since it is as if a pregnant nurse is used for a suckling child; metals and plants have the same food, so that the nature of the place will hardly suffice for both. But metals drink up more than trees, because the reach[151] of metals is much larger than that of trees, just as sea beasts are larger than terrestrial animals.

Silver being a less abundant metal, I find there was in Agricola's account a silver mine thirty feet long, three- quarters of that wide, and sixty high. This makes clear its resemblance to a tree: a tree's height is the greatest, then comes the length or span of the branches, and smallest is the thickness, which in mines is regarded as the width.

So if the dimensions are like that in the case of silver, what are they for copper, lead, iron, and sulphur? Ultimately, what are they in the stones themselves? But not on the same basis as that on which sea beasts alone outdo terrestrial ones in size—that is, in supply of humour—but because the weight in metallics &366 and stones is not suspended and presents no danger; in trees, it does. Since trees in fact dangle, they are easily blown over, and nature's care is brought to nought.

In connection with their resemblance, as I said, trees and metals alike enjoy a northern outlook, and possess four virtually essential parts: root, bark, substance, and veins. The root for a stone is another stone, or earth, as we will explain at the appropriate place; for a metal it is a metal, or a metallic, or earth. Bark is manifestly different from the rest of the substance, in its position and hardness; veins are clearly visible within the substance. So what is a mine[152] but a plant

[150] *Pinus pinaster* (*OLD*).

[151] "propago."

[152] "fodina."

overwhelmed by earth and stones? It is, as I said, either metallic earth of which I spoke, or a more important juice, or a metal, or a stone. Common features of all metallics are to create increased hardness and coldness. Eretrian earth[153] indeed, and metals, and stones, and the majority of metallics are cold. Yet even if some are dry, they still soften with plentiful fat, as do asphalt and jet.[154] They are dry because of being earthy. Fire—or rather, heat—can do heating, but not moistening.

Furthermore, almost all metallics have to have an evil taste, or none—none in the case of pure stones and pure earth, evil in the case of the rest. The reason is that they are rescued with difficulty from combustion, and are dry, as we said; but sweet ones are moist. And even if some moistness is present, and a pleasant taste is mixed with the nasty one, it does not overcome it, but is overwhelmed. For if you have &367 mingled a little gentian with a lot of milk, you will get an unpleasant taste.

Odours are different; the more potent usually effaces the weaker one. Copper is pungent and has a very evil taste; iron is mildly pungent; then there is white lead, which we call "stannum."[155] Alum is astringent with pungency, and so is copperas,[156] but more pungent, and so are the rest, such as sulphur and bitumen. Silver, on the other hand, provides a nice and nearly sweet taste, and gold has a much better one, but it is not prominent.[157] The tastes are recognised if something moist is contained and heated in vessels of the stuff; or else if some of a metallic is diluted in wine, gravy,[158] or water, and stays a long time in them.

Again, if metallics are constituted from condensed moist cold, they are all liquefied by fire, as sulphur and metals are; some though solidified by heat are liquefied by cold and water, as are alum, salt, blacking,[159] nitre; some are only softened

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[153] This earth from Eretria on the island of Euboea (close to the eastern coast of mainland Greece) is mentioned by Celsus (Bk 5. 15; Loeb 2: 11) as an emollient.

[154] "Gagates lapis": mentioned in Plin. *Nat. Hist.* 36. 141 as product from a river in Lycia.

[155] Though this word means "an alloy of silver and lead" in Pliny (*L&S*), it came subsequently to mean "tin," hence the confusion here.

[156] "calchantum"; see n. to Book II at 131 (1560) on this.

[157] "praestat"; Scaliger (*Exercitatio* 104(5) [385]) does not adopt the meaning given in the translation here, nor does Maclean "Interpretation of Natural Signs," 243); they regard Cardano as asserting that gold *presents* no odour, which, as he points out, makes it difficult for its odour to be assessed!

[158] "ius."

[159] "atramentum"; Georgius Agricola (*De natura fossilium*, 1: 176–77, cited in Nenci, 465 n. 65, refers to "salt, nitre, alum, atramentum sutorium"—the same phrase is used by Fernel; see Forrester and Henry, *Jean Fernel's On the Hidden Causes of Things*, 114—tailors' blacking. It is copper sulphate (Crosland, *Historical Studies in the Language of Chemistry*, 72), which is blue but can blacken leather. See also n. on "chalcanthum" in Book II at 131 (1560).

by water, like most stones. Agricola records that he has seen marble partly softened by water, after lying in it for a long time. This must be earthy—earthy things never completely liquefy. And so things that do are watery, even though[160] things that cannot be completely liquefied by moistness are earthy. Consequently juices consist of a watery substance, as do alum,[161] bitumen, sulphur, salt and nitre, and copperas, and many things of that sort. However, I would rather refer to salt as earth with juice, but it is not in my current plan to deal with details, but with points contributing an illuminating example or usefulness.

Some less common juices do exist, like the one found at Annaberg[162] in a passage[163] of the Emperor Otho's mine[164]—&368 hard and shiny white, and so bitter that it killed mice through gnawing it. We will turn now to better known ones, among which are alum of "Rocha," a replacement for a liquid of the ancients, with such an astringent power that if you heat it in water till it dissolves, and immerse our usual paper in the water and then dry it, it holds ink excellently, not allowing it to spread or scatter nastily, even if it was very poor paper. The[165] method is: heat up an ounce of alum per pound of water, till a third part of the water is left. Then spread the paper over a smooth table, and wet it on both sides with a sponge dipped in this.

The red stuff from alum is superior.[166] The sign that it has taken up the alum is that it glitters. It improves goose feathers in the same way, and skins; and it stops wines going cloudy in vessels. The alum that people call "alum of Scaiola"[167] is the "Astrum Samium"[168] of the ancients, and is not of a kind with the juices, nor is feather alum,[169] which is constituted from earthy parts, so that if it is lightly rubbed and scattered on a bed, it provokes constant itching—it has sharp and pungent parts. And if lamp wicks[170] are made from it, they do not take fire, but the oil keeps being consumed, the wicks remaining. This is a general feature in

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[160] Sense here incompletely clear: "Itaque quae perfectè liquescunt, aquea sunt, etiam si ab humido, quae non possunt perfectè liquescere terrea."

[161] Scaliger protests (*Exercitatio* 104(6) [385]) that alum is Alum *Rochae*, which he asserts means "rock alum," so it cannot be treated as a liquid.

[162] In Saxony, in Germany.

[163] "cuniculus."

[164] Mentioned previously in this Book at 338 (1560), as a silver mine.

[165] This sentence first appears in 1554, the next one in 1560, and the next after that in 1554.

[166] "Praestantius ex alumine rubrum est."

[167] The phrase here may mean "alum from shale" (German: Schale, a lamina), and alum can be derived from shale.

[168] Probably talc or china clay; compare Scribonius Largus, 24, where the phrase "cretae Samiae, quam vocant astera" occurs (*OLD*). The phrase recurs later in the present work, in Book XVIII at 1155 (1560).

[169] "alumen plumae."

[170] "ellychnia."

nearly all this sort of encrusted stone. And a green liquor emerges in Eisleba from pyrites, also from another stone that can split when placed on a fire; this liquor is collected after the fire has been put out, and is no longer susceptible to fire.[171] Similarly, Agricola states that from asbestos[172] at Rome napkins[173] are made, and at Verebergo[174] in Bohemia tablecloths, and these are cleaned not with water but by fire. &369 And tables are made in Boldecrana from scaly Magnesian stone, of a silvery and leaden colour, which are cleansed by fire without being damaged. The thinner part yields [443]wicks[175] for lamps. Some people will think all this beyond belief, but it is not only true, but necessary too, and easy to discover. For although almost all stones resist fire, especially for a brief time, the scaly ones are spun,[176] because of their threads. So if you spin a material resistant to fire, you will be able to make napkins, tablecloths, and wicks invulnerable to fires.[177] Who can doubt that anything spun can be woven? Thus too napkins are made not only from flax and hemp, but from esparto-grass[178] or broom. Now we only use broom for sweeping, but if a handyman is available, it is also of use for making cloths—anything ductile can be spun, and what can be spun can be woven. "Ductile" means anything consisting of tough and tenacious moistness. There is insufficient juice in feather alum to let you spin it. And it should not be thought miraculous that a wooden tower has remained intact when fires were set against it, because it had been besprinkled with this kind of alum.

But bitumen has as much power[179] as alum; however, there is more than one kind of it: there are what is properly called asphalt, and pissasphalt, and naphtha, jet, ampelites,[180] maltha,[181] Thracian stone,[182] mineral charcoals, amber,[183]

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171 "ignem amplius non sentit."

172 "ex Amianto lapide."

173 Nenci cites Plin. *Nat. Hist.* 19. 19, where Pliny remarks that he has "seen napkins made of it glowing on the hearth at banquets and burnt more brilliantly clean by the fires than they could be by washed in water." He also gives the Agricola quotation, which is Georgius Agricola, *De natura fossilium*, 5. 258–59.

174 Nenci, 470 n. 72, cites Agricola referring to "*Saxonia* Verebergi," and so this place presumably lay where Saxony adjoins the northern boundary of Bohemia, now the border between Germany and the Czech Republic.

175 "thryalides": these (*OLD*) were thick leaves from a plant, a kind of mullein, which were used as lampwicks (Plin. *Nat. Hist.* 25. 121).

176 "nentur," from "neo," to spin.

177 The next four sentences first appear in 1554.

178 "spartum," Spanish broom, a plant of which ropes, mats, nets etc. were made.

179 "virtus."

180 A bituminous earth, ἀμπελῖτις to Strabo.

181 A kind of thick, fatty petroleum from Samosata on the Euphrates, "fossil tar," the flame of which could be extinguished only with earth (Plin. *Nat. Hist.* 2. 235).

182 "Thracius lapis"; *OLD* considers that this may have been an asphaltic lignite.

183 "succinum."

ambergris,[184] petroleum, camphor.[185] There is sufficient agreement about all of them, except camphor; some people call it caphura[186]—I give in, I don't make an issue of it, there is uncertainty about the &370 thing itself; whoever you are to be so fussy, I leave you to sort it out. So[187] when people find bits of wood in it, they suppose that, rather than bitumen, it is the teardrop of a tree called Capar,[188] which grows in the island called Butei, otherwise called Zebut; it is five and a quarter degrees away from the Equator towards the north, 186 from the Fortunate Islands.[189]

But if amber, which is certainly bitumen, takes fire, and the smoke is caught in a damp cloth, it smells of camphor. However, a physician is not much concerned to know this,[190] but to know that camphor, amber, and ambergris are of a kind with bitumen. And it follows too that if any of these flows out of trees, there is nothing to stop something like it being generated in the earth's bowels.

But camphor seems to derive its ultimate origin from trees. By nature it is not so matt white, but gets like that on distillation. Distillation in fact generally whitens, not just by withdrawing all dirt, but because it creates a rarefied substance which is therefore permeable to air. So camphor is excessively dry, so much so that if carried in the bosom of virgins, it makes young men impotent.[191]

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[184] "ambra"; this forms in the gut of the sperm whale, and emerges to be found floating upon the sea, on the sea-coast, or in the sand near the sea-coast.

[185] Agricola, cited here by Nenci (*De natura fossilium*, 4. 229) refers to all these diverse items as of the same ultimate origin.

[186] *Liddell&S* give καφουρά for camphor.

[187] Part of this sentence first appears in 1554.

[188] Camphor.

[189] The Fortunate Islands are the Canaries; on this see see n. to Book II at 200 (1560), also Nenci's note on Petrus Martyr at that point. On "Butei": Nenci, 472 n. 77, cites Antonio Pigafetta, *Viaggio atorno il mondo*, in G.B. Ramusio, *Delle navigationi et viaggi*, 1: 364a. This from Nenci's note is clearly Cardano's source; the island is there called Burnei, not Butei, 5.25°N and 176.66° east "dal nostro" (Seville). The island is shown on Mercator's *Atlas sive Cosmographiae Meditationes* (1594) as obviously Borneo, otherwise known as "Cattigara"; it is depicted lying on the Equator, which it is, though mostly above it, and bisected by longitude 150°. (Its centre is in fact roughly 115° E of the Greenwich meridian.) Cardano's "186" may be measured from a zero such as Nenci says Pigafetta calculated as the latitude (?longitude) of the line of "ripartizione" 30°W of the island of Ferro (Hierro) in the Canaries. Nevertheless, it is difficult to reconstruct the basis of the 186 degrees of longitude that for Cardano separate the island from the Canaries.

[190] The remainder of this sentence along with the following four first appear in 1554.

[191] One of Cardano's own problems as a young man was impotence—in *OO* 2. 76–77, *De utilitate ex adversis capienda*, Bk II, chap. 10, *De veneris impotentia*, Cardano writes that he suffered this "incredibile malum" at the age of 21; carried along somehow by a "peste pueris familiari," he started intercourse with a girl and felt potent enough,

The same thing dries up and whitens ulcers; it is of very rarefied substance, and for these reasons fends off sleep.

Ordinary people[192] call black ambergris "Gagates."[193] It is made into rosary beads;[194] it is bright and clear, so much so as to be included in the stones by many people; it is black in colour, and attracts straws; pilgrims from Spain bring us images;[195] it takes fire, a feature common to the whole kind of bitumen.[196] There is a tale that when drunk with water it makes non-virgins &371 urinate, but not virgins—more a fable than a credible tale.[197] It does stimulate some women more, and nothing stands in the way of those who have been deprived of their virginity; as the bladder neck is attached to the neck of the uterus, any non-virgins are more upset by things that have regularly troubled the bladder. People say too that it is extinguished by oil, not by water; we have mentioned this before. This is in fact almost a universal special feature of bitumen, but this fire is not immune to every water, nor extinguished by every oil; a lot of water chokes all fire, and a little oil puts nothing out, so that these details can be considered as said metaphorically. It is also believed, with reason, to stimulate epileptics, as

but then things went wrong, he had to return to his home country and was impotent till he was 31. It drove him to utter despair and to fear of matrimony—sometimes three whole nights with a girl, and no luck. However, things did get better for his potency, and he also grew to reflecting on the benefits of continence—physical strength, longer life, security from venereal disease. And he concludes by offering some therapy: eat bulbous vegetables, hazelnuts, and a moderate amount of sugar and bread; drink moderately of "mombasij" (no doubt the wine from Monemvasia, on the east side of the Greek Peloponnese, also known as Malmsey); consume scrapings of deer or bull penis on an empty stomach. Scaliger (*Exercitatio* 104(8) [387]) doubted whether camphor could in fact "dry up semen," and did an animal experiment: he administered camphor to a greyhound bitch in heat, in its drink, its food, and up its nose, to cool it off. And he ordered camphor to be hung daily from its neck and applied to its genitalia ("natura"). All in vain: it copulated, it conceived, it gave birth. Genuine camphor?—Scaliger reckoned so. I think the use of a bitch stemmed from the idea that camphor dries up semen; the male might be made impotent, and if not, the semen would be dried up in the female subsequently.

192 "vulgus."

193 The word from which "jet" is derived—see n. 154 above.

194 "Fiunt globuli pro precibus: splendet et lucidus est . . ."

195 Images made of ambergris, evidently.

196 The following four sentences first appear in 1554.

197 Nenci (475 n. 82) traces this tale back to Albertus Magnus.

amber does.[198] But the ancients wrote that it also evokes[199] that disease, and it can do both. The cause common to both is moderate hotness, rarefaction and dryness. Also because it is fatty and also odorous.

There has been great debate about amber right up to the present day; however, it is bitumen, and some fat of the earth out of the sea's tide.[200] Much is fished up among the Sudini people of Prussia, with a herb which grows with it and resembles pennyroyal.[201, 202] And if it were to take origin from a teardrop of herbs or trees, it would still be bitumen combined with fat of sea and lands, and tempered by their heat. There are several kinds of it. The shiny white one is the most costly, sweet to the taste and very well scented, so much so that a fumigation with it in rooms against the plague (it does help) makes the room smell all right up till the third day.[203] While everything that &372 smells well is being used for fumigation, it frees the air from every defect, by extracting corrupt vapours; the more fragrant things smell, and the more slowly they are exhausted, the more freeing they do. Things that are hot and dry exhaust the vapours more quickly. This is why a large fire is an outstanding protection against a pestilent state of the air, as is a fan; vapours impair the air, both from the nature of the place from which they arise, and because they prevent the Sun's rays getting in. This is why people say that when the Ioachimica valley[204] in Germany was uninhabitable because of dense woods and bogs, it was made healthy by drawing off the waters into tunnels and ditches, and pruning the woods. And so it is no marvel that glowing amber is of double assistance in improving the air—both by being dry

[198] Pliny (*Nat. Hist.* 36. 142) discusses the properties of Gagates = jet, and says that the kindling of jet drives off snakes and relieves suffocation of the uterus. Its fumes detect attempts to simulate a disabling illness or a state of virginity. Moreover, it cures toothaches and . . . scrofulous tumours. But not epilepsy. Dioscorides however (*De materia medica*, 5. 145; ed. Wellmann, 3: 96) says that jet can be used as a test for epilepsy, and evokes "hysterics"; it is also good for gout.

[199] "provocare"—could it possibly mean "stops" or "does battle with" here, to justify the contrast with "stimulating epileptics"? Adams, commenting in his translation of Paulus Aegineta (3: 427), writes at length what various Arabs thought about camphor, but none of it relates to epilepsy, and it seems more likely that "stimulating epileptics" does not involve bringing on their fits. Nowadays, however, fits are recognised as a manifestation of camphor poisoning.

[200] The following two sentences first appear in 1554.

[201] "pulegium."

[202] Nenci (477 n. 83) has traced to Georgius Agricola a detailed account of the procedure followed during this search for amber, and the properties of the amber found.

[203] The following eight sentences first appear in 1554.

[204] This is the Joachimstal valley on the Saxo-Bohemian border. It was the site of an early silver mine; the "thaler" coin was originally made from its silver, and in the twentieth century it was the source of radioactive material used by Marie Curie, the pioneer investigator of radioactivity.

and by smelling good. This is the way in which long ago Athens was twice freed from plague by the two physicians Hippocrates and Acron[205]—I mean by the flames of good-smelling timber, not ordinary flames, but huge ones.[206] Ordinary fires, kindled with barely odorous material, fail so completely to cure the pestilent air (the more so if the blessing of winds is absent) that the plague is actually powerfully exacerbated. Thucydides[207] therefore records that when corpses were so numerous that they were placed on funeral pyres, the pestilence was a good deal increased. So it is evident that through almost the same causes, amber mixed in the medicaments contributes much to the same disease. It is mixed in either for its odour or to produce drying, because the assistance it offers for attracting in that situation is quite obvious; it attracts everything light—straws, stalks,[208] thin scrapings of metals, &373 leaves of basil, though Theophrastus mistakenly denies it.[209] The reason for this is that moistness has fatness and stickiness, and when that is sent out, the moistness moves towards [444]anything light, as fire too does to fuel; hence if it is rubbed, it attracts rather vigorously, on account of the heat too.[210] The evidence is that every gemstone when rubbed with a woollen cloth attracts both straws and dry leaves to itself; when they have stuck, they are in motion; because the fattiness lurking in the wool is attached to the gemstone, and warms up with rubbing; but in amber it is dissolved. Hence gemstones do not attract on rubbing with linen, but amber does. The lodestone[211] and amber do not in fact attract on the same basis; amber attracts anything light, the lodestone only attracts iron. When something is in between, amber does not move a straw, but a lodestone does move iron. Amber is not attracted in turn by a straw, but lodestone is attracted by the iron too. A straw is not moved in a particular direction, but on contact with a lodestone, iron makes now for the north and now for the south. Finally, amber's attraction is much assisted by warmth and

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[205] Physician at Agrigentum around 500–420 B.C., mentioned by Plutarch (*De Iside et Osiride*, 79–80), though not by Thucydides.

[206] Galen (*De theriaca ad Pisonem* 16; K. 14: 281) says that during the plague of Athens, Hippocrates purified the air with fire and with high-quality flowers, to good effect. Plutarch credits the physician Acron on the same occasion with making similar use of fire (*De Iside et Osiride*, 79).

[207] In his *History* at 2. 52 Thucydides records the abandonment of all conventional burial rites, but does not actually state that this aggravated the plague.

[208] "festucas."

[209] Nenci cites Georgius Agricola for this. However, this statement of Cardano about Theophrastus is not true. See Caley and Richards, *Theophrastus on Stones*, where sect. 29 (51) runs: "And since amber is also a stone . . . the power of attraction would belong to this too." See also 111–12 and 116–17 for discussion of this attractive power as described in antiquity; "The various statements of Theophrastus . . . are certainly the earliest account of the properties of amber."

[210] The following two sentences first appear in 1554.

[211] "lapis Magnes."

friction, but a lodestone's only by a portion of the lodestone being made purer. The conclusion?—the attraction of amber is surely like that exerted by a cupping glass from the fire and other hot things, because of that well-known innate heat, which sticks to room walls, as I said, and makes rooms smell nice even till the third day. In every bitumen there is actually the fatty hot moistness, which makes it burn readily too. But for attracting, choose amber among the bitumens, and the ash-coloured amber among the kinds of amber, the one that is dug out on this side of the mouth of the Vistula at Puceca[212] on the seashore; it, &374 as Agricola reports, when rubbed with iron attracts leaves from the ground to itself two feet up in the air.[213] So this is the one most suitable for ointments. A shiny white one is extracted from the German sea, from which gambling dice are commonly made. And there is a honey-coloured one, and a wine-coloured one, and a golden one, which is usually found in a spring in Suevia,[214] beside a convent named after Lake Degera.[215] All sorts of little things shine out in amber—flies, ants, little fish, leaves, scrapings—captured by the tenacious moistness of the amber, they cannot get free, then as plentiful moistness flows in, they solidify and dry up, and so cannot decay, and shine out from their eternal tomb, a grander one than the Mausoleum Artemisia built.[216] Of itself, amber has little odour, but when it is burned, it emits a pleasant odour of myrrh.[217] Honey-coloured amber is counterfeited with white of egg, and saffron, and teardrop of tragacanth.[218] Hence cunning people mix ants, midges, flies, particles of iron, scrapings and straws here and there, and then add a very slender portion of genuine amber into the ground-up dust, to make it smell good and attract stems. There are people too who maintain that not only white of egg (this is perfectly true) but also its yolk, when cooked and exposed to the breeze on a stone, gets so hard that it changes into an actual species of stone. In fact it hardens and solidifies because it is fatty, unless it decays. It does not do so, because it is devoid of watery moistness. Yolk of egg is also devoid of watery moistness when it is baked.

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[212] This is evidently now Puck on the Gulf of Danzig, some 40 miles north of the present mouth of the Vistula (now the Wisła) river.

[213] Nenci has traced this to Georgius Agricola, *De natura fossilium*, 4. 244.

[214] An area now consisting of Baden-Württemburg and parts of Bavaria and Switzerland. The name persists as Schwaben in Germany, with its capital at Augsburg.

[215] The Tegernsee, in Bavaria; the convent was dedicated to St Quirinus (*Orbis Latinus*, 3: 463).

[216] The Mausoleum that his Queen Artemisia built for Mausolus on his death in 353 B.C. was at Halicarnassus in Asia Minor and was one of the Seven Wonders of the World.

[217] The remainder of this paragraph first appears in 1554.

[218] "Dragagantha" to Cardano; tragacanth is the gum extruded from certain shrubs of the genus *Astragalus* (hence the word "teardrop" here), and is still in use as an agent to suspend heavy insoluble powders and for similar purposes in applications for the skin.

Ambergris[219] is more fragrant than amber,[220] as &375 is recognised by its very high market price. It comes into existence near Sichris,[221] a small town of Arabia Felix. Its power upon the brain is remarkable; much of it has a heavy smell because of the extent[222] of its odour; it has thin portions mixed with thick ones.[223] It is thought to be the semen of a terrifying monstrous fish of the whale kind, with a head of stony hardness. It comes into being in the African Ocean, and its name is "ambar";[224] hence the name "thymiamatum"[225] was introduced. There are three kinds of it, on a range of colour, odour and weight. The matt white is the lightest, is odorous and is best; the shiny black is the heaviest, odourless and little valued; the ash-coloured is midway between these. At one time the Sultan, the tyrant of Egypt, used to mix ambra with beers,[226] looking after his pleasure and his health at the same time.[227] For us[228] ambra is more expensive and our wealth not royal—we could use asafoetida juice or frankincense for the mixing. For kings the former, for private people the latter are luxurious and elegant, and suitable for one's delight.

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219 "ambra."

220 "succinum."

221 Nenci, 481 n. 93, identifies this name as mentioned in Agricola (*De natura eorum quae effluunt ex terra*, bk. 1, 105) as a town in Arabia Felix at which amber emerges.

222 "magnitudo."

223 The remainder of this paragraph first appears in 1554.

224 This fish is mentioned by Leo Africanus; see n. to Book II at 160 (1560). In Pory's translation (3: 949) of Leo's Book IX, "Of the strange fishes of Africa, and first of the fish called Ambara," his account runs: "The fish called Ambara, being of a monstrous shape and bignes, is neuer seen but when it is cast vp dead vpon the sea-shore: and some of these fishes there are which containe twentie fiue cubites in length. The head of this fish is as hard as a stone. The inhabitants of the Ocean sea coast affirme that this fish casteth forth Amber; but whether the said Amber be the sperma or the excrement thereof, they cannot well determine. Howsoeuer it be, the fish may in regard of the hugenes be called a whale."

225 This word means "used as incense" (θυμίαμα) and is found in Galen, and in a recipe in Celsus, *Medicina*, 5. 9, referring to a plant known as "ammoniac" (or "hammoniac") with a milky juice used by Celsus for a variety of purposes.

226 "cereis," derived either from "cerea," a Celtic word for beer, or from "cereus," a wax taper.

227 This is not quite what Leo Africanus wrote on this matter (Book VIII, "Of the Testecana" [the master of the Soldan's wardrobe]; Pory's translation 3: 893) "Moreouer there were other officers . . . who furnished the place of the Soldan with rich hangings and carpets, and made prouision also of torches and tapers of waxe mixed with amber, which serued both to shew light, and to yeeld most fragrant and odoriferous smels."

228 Reading "nos" with 1554 and Nenci; the "non" of 1560 appears a typographic slip.

Petroleum is an oil which flows from bitumen of itself through the power of heat, very rarefied and hot, strong-smelling; ordinary people call it rock oil;[229] it is a real help against chilly pains, even prolonged ones. Less evil-smelling (it seems to me to smell all right) is what is properly called asphalt, like pitch, only harder, more glittering, and less evil-smelling even to those for whom it has an evil smell.[230] It is dug up from a lake in Palestine. This sludge has such power that for about fifteen thousand paces around no trees turn green, or flower, or produce fruit, as if heaven were enraged against these lands.[231]

Coals consist of fatty light earth, matt black. They are dug up &376 throughout Meissen,[232] in a mountain near the town of Zuicca[233] located towards Mulda.[234] They are of use to blacksmiths. Their value is less than that of asphalt, but of the same kind. Indeed, just as amber and bitumen usually smell all right, so sulphur always smells bad. Both share the property of igniting easily, but sulphur does so more easily, and asphalt over a longer time. But beware in case instead of asphalt (the bitumen) you alter a letter and read "Aspalathum," a scented tree, which I think our people call Santhalum.[235]

The use of sulphur is exceptional and manifold; from it originally gunpowder[236] is made, for which it is indispensable; it is stuff suitable for every fire, as we showed previously. It even resists water, so as to remain for many centuries immersed in it; as mostly happens nowadays, it is safer from its enemy, water, than it is from its friend, fire.[237]

The same sulphur when melted is better than anything else at precisely reproducing shapes embellished with gems. And when smeared on or used as a fumigant, it kills, prevents and drives away snakes, ants, and midges.[238] Smeared

[229] Nenci, citing Brasavola (see n. to Book II, 131 [1560]), identifies this as "oil of Mount Zibi, or rock oil, which is plentiful in the Mutinensis district" (Mutzschen in Saxony near Leipzig: see *Orbis Latinus*).

[230] The remainder of this paragraph first appears in 1554.

[231] The Dead Sea, lying between modern Israel and Jordan.

[232] "Misena," "Misna," a place in Saxony in Germany.

[233] Now Zwickau.

[234] A town in Saxony.

[235] Sandalwood. Scaliger (*Exercitatio* 104 (13) [393]) denies the identity of aspalathus [*sic*; a prickly bush] and sandalum [a non-prickly proper tree], and points to other differences.

[236] "pyrius pulvis."

[237] The Latin runs: "ab hoste quod plerisque nunc contingit, tutius aqua, quàm ab amico igne." The translation has profited here from discussion with Professor John Richardson, of the University of Edinburgh.

[238] Aristotle (*De sensu et sensibilibus*, 5. 444b9–445a1) refers to small insects and certain shellfish having a sense of smell, and hence being destroyed by evil odours such as those from sulphur or bitumen.

on and as a drink, it removes scabies, leprosy, and the French disease.[239] But its oil is of stronger power. How this comes about we will describe lower down.[240] Reinerius Solenander reports that when a little is placed close to the ear, it crackles like burning coals. When fire's nature is actually brought close, particularly when the air creates movement, it gives off vapours—not always, but it happens when it is broken.[241] Salt has more of a share of earth than sulphur does; hence its juice can be discussed along with earth. It contains oil, if it is mingled with bitumen. Hence Arrian reports in his *History of India* that among the Ichthyophagi[242] people collect an oil from salt.[243] &377 Evidence of this is also that olives flourish along the sea shore—a salty soil, and significantly fatty. But, as I said, everything contains oil in this way, which can be extracted by the power of fire. But it cannot hold much unless it has bitumen mixed in. There is a kind of salt that is dug up,[244] such as what we call saltpetre[245] and ammoniac.[246] [445] This is the bitterest of all, like what is obtained under burning hot sand. In fact, when a salty thing is cooked further, it turns bitter, on Galen's authority.[247] And so sal ammoniac can be made artificially, although many have laboured at that in vain. Sal gemma glitters like crystal, more brightly than artificial salt. Indeed, in everything made artificially and prepared without mixing,[248] nature makes a

[239] See on this especially J. Arrizabalaga, J. Henderson, and R. French, *The Great Pox: The French Disease in Renaissance Europe* (New Haven: Yale University Press, 1997).

[240] The remainder of this paragraph first appears in 1560.

[241] Nenci (486 n. 105) identifies the source as Rainerus Solenander, *De caloris fontium medicatorum causa, eorumque temperatione* (Lyons, 1550), lib. 1, cap. 11, *Sulfuris species et differentie*, 105. Solenander (1524–1601) pursued interests in medicine and philosophy in Italy (Bologna, Pisa, Rome, and Naples) and then in France, subsequently returning to Germany where he had been born at Büderich near Wesel (*Biographisches Lexikon*, 2nd ed.).

[242] Fish-eaters.

[243] Arrian (*Historia Indica*, 29. 14) wrote that the Ichthyophagi collect crabs and oysters and shellfish; there are natural salts in the country, and from these (it is unclear whether from the fish or the salt) they make an oil (ἀπὸ τούτων ἔλαιον ποιέουσιν).

[244] "fossilis."

[245] "Salpetra."

[246] "Sal ammoniac" may be intended here; the phrase nowadays means ammonium chloride, which has been known since the early Middle Ages; it was prepared then by heating salt with the soot of burning camel dung. The ammonium carbonate in the dung reacted with the salt to form ammonium chloride (Taylor, *Chemistry*, 506). But in classical times sal ammoniacus or hammoniacus was connected with the Egyptian god Ammon or Hammon whose famous oracle was in Libya, and "sal ammoniac" appears then to have been a form of rock-salt (*OLD*).

[247] Galen, *De simplicium medicamentorum facultatibus*, 4, K. 11. 693: ὅ τι γὰρ ἂν ἁλυκὸν ἐπὶ πλέον ἐκθερμήνῃς, ἔσται σοι πικρόν—anything salty you heat further, you will find bitter.

[248] "elaborantur absque compositione."

similar thing; hence sulphur that comes into being of itself is far more costly than the rest, though not as much more useful; the same is the case with copperas[249] and the others.

The most rarefied among the kinds of salt is saltpetre[250]—it is midway between salt and nitre.[251] Nitre is found especially in Nile sand. Albertus named "the Great"[252] recounts that water collected at Goselaria[253] at the foot of a mountain that was rich in copper turned to nitre when being collected.[254] A part of this that was more shiny white and slack[255] hangs down in caves like icicles. And sometimes it sweats up out of the soil, and is called Aphronitrum—the foam of nitre, so to speak.[256] It has been wrongly believed in our time that both of these had vanished, and hence the composition of Diaspoliticum[257] has been confused. Nitre is more bitter than salt, and less salty; saltpetre is in between, as I said. It consists of the most rarefied and driest particles, because it combines from some decay; hence it turns up in &378 ancient cements, and where the dung of beasts of burden has rotted in the earth. What is remarkable is that if saltpetre is formed into a heap when it is extracted from the earth, after five or six years it makes the harvest more plentiful. And it ought not to be ridiculous to talk of sowing salt, for, as I said, if either the piles of earth from which it was extracted get warm under huts[258] or else if the saltpetre is dissolved in water and scattered in heaps on the earth, just like wheat seed, after five years the harvest is made more ample. There are actually powers in everything, so that they make something become in potentiality what it was previously in actuality [*sic*]. What is in potentiality proceeds also to actuality through the Sun's power; hence worms and flies leave behind in the places they occupy the means by which a faculty is supplied for the generation of other similar things and the multiplication of their kind.[259] This is how it is collected: into perforated cisterns full of ox or horse dung—or,

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[249] See n. to Book II at 131 (1560).

[250] "halinitrum"; see n. to Book II at 92 (1560).

[251] Soda; on this and halinitrum see n. to Book II at 92 (1560).

[252] Albertus Magnus.

[253] Goslar, in Hanover in Germany.

[254] Nenci traces the reference to Albertus Magnus, *De Mineralibus*, lib. 5, tract. Unic. *De mineralibus quae media inter naturas lapidum et metallorum esse videntur*, cap. 7, *De natura nitri*.

[255] "laxa."

[256] This is the meaning of the Greek word Aphronitrum.

[257] This is Di*o*spoliticum or Diospolitikon, a carminative (i.e. it releases flatulence, or "brings up the wind"). See Galen, *De sanitate tuenda*, 4. 5 (K. 6: 265, 430 etc.) for recipes and uses. Paulus Aegineta's recipe (VII. Sect 11, trans. Adams, 3: 519) includes cumin, pepper, ginger, green rue, and natron (not nitre); this last ingredient explains the mention here.

[258] "tuguriis"—huts or shacks (*OLD*).

[259] The remainder of this paragraph first appears in 1554.

what is better, pigeon excrement—water is poured, and later taken out and used, to the extent of a third part of it; then a third part is poured over other dung and heated[260] and taken out again; finally the third part remaining is placed in the open air and solidifies into saltpetre. What has been washed out is cleansed afresh with other water, and on the same plan, what is of use is extracted. But if, as we will explain further on, saltpetre has passed into water for the sake of pleasure,[261] the water is heated for about an hour and taken out with a spoon; and when it has just begun to freeze on the floor,[262] it is taken away from the fire and allowed to &379 solidify.

And so, to return to the nature of saltpetre, there is a rarefied part in it, mixed with water and earth in salt, which while burning makes the earthy parts scatter; and consequently salt and saltpetre placed on a fire jump up and crackle. And when in the presence of my father-in-law at the fire, a slab of very old[263] roof tile was placed on the fire, all at once it crackled, and fragments shot out in various directions with a great bang, but surprisingly without hurting any of those nearby. The reason for this was, I believe, a modest portion of saltpetre enclosed in the tile, because it was an old one.

On the same basis, candles made of tallow or salted wax crackle, and last much longer than the rest. Among the kinds of salt, chali[264] salt or alum is usually replaced in the crucible, not just as a treatment for glass to make it ductile, but also as material. It is imported from the East; but Brasavolo of Ferrara[265] asserts that the best is made from a herb that springs up beside Comum[266] on a bank of salty waters. And if the story is true and fit for us to trust, growing the herb would be no small money-spinner[267] and this technique would be quite lucrative. It is well established that this sort of salt is made from the herb Usnen,[268] one as big as a tree, with a salty taste, which some people think is the original kind of Anthyllis. A more rarefied substance of salt is the matter for copperas,[269] of

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[260] "excoquitur."

[261] "voluptatis causa"—obscure.

[262] "cum primum in pavimento gelascere coeperit"—meaning obscure.

[263] 1560 reads "peruestutae" but this is a typographic slip for "pervetustae" which Nenci reads.

[264] This word is the origin of the first name of potassium, kalium, = K; Brasavola, cited by Nenci (489 n. 114), spells it "cali" and says it is an Arab word for the herb mentioned just below. Scaliger (*Exercitatio* 104(18) [396]) says it is the Arab name for a plant "which we call soda," and he supplies other names too.

[265] On Antonio Musa Brasavola see n. to Book II at 142 (1560).

[266] Comacchio, near Ferrara in Italy; Brasavola's original text, cited by Nenci (489–90 n. 114), gives "Comaclum," not "Comum."

[267] "non parvum compendium rei pecuniariae fieret."

[268] Arabic name for a herb known to Avicenna, synonyms being "kali" and possibly hyssop and soldanella.

[269] See n. to Book II at 131 (1560).

which there are such diverse species that it is a major task to disentangle them. The common people call copperas vitriol; it blackens so much that writing ink is made from it. This dust is of an ashy colour and &380 after you have ground it up, when it is put in wine or water it makes it very black at once. The reason is that it is a juice, and quite dense, and consists of rarefied and charred[270] portions; being a juice, it is dissolved into moist substance, and can stick, and gives a pen no trouble—because it would not enter into contact with earthy stuff, even if it were reduced to a very fine powder. When it has been thoroughly burnt, it excludes the illumination and makes it black. And as it consists of the most rarefied parts, it produces a black writing ink of minimal stickiness. And this makes it easy to deduce its powers. More select than it is Misy,[271] which is called Roman vitriol; its smoke is so heavy that it even kills trees, and disfigures woods; Misy is sometimes bright, and glitters with a sort of golden droplets. In every kind of thing that is mined[272] there is something that glitters—among the juices, for example, Misy; among the metals, gold; among the stones the gems and marbles; among the earths the silvery ones. A sheen develops when compact matter is polished by art or by nature; but in every kind of thing that is mined, something compact has to be found. The portion of calchantum[273] or Misy that foams up[274] and is not worked upon is called Cuperosa,[275] but by Galen and the rest of the ancients, chalcitis.[276] It is shiny white, close to the nature of copperas,[277] not bright, and notably emetic.

When copperas or Misy is burnt, a very sharp and hot oil is drawn off by the fire's power through glass vessels;[278] alternatively, put two pounds of calcanthum in a glass vessel, and the glass vessel in an iron one. Distil, and when no more water emerges, put the vessel's neck in the &381 neck of another glass vessel, so that it is not ventilated.[279] Cover both with fireproof clay, and draw off the oil in bags—that way, you will manage to finish the task in a single day. If anyone

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270 "exustis."

271 *OLD* is very rich in classical refs. for this, giving the meaning "a copper ore, probably copper pyrites."

272 "fossilis."

273 See n. to Book II at 131 (1560).

274 "quasi spuma eruitur."

275 A medieval Latin word, possibly a corruption of "cupri rosa," "rose of copper," that originally referred to a mixture of copper and other sulphates. It passed into French as "couperose" and became "copperas," which nowadays only means ferrous sulphate, but the word "copperas" has been used in this translation as synonymous with "calchantum"; see n. to Book II at 131 (1560).

276 A word used for instance by Celsus (5. 1) for the same composite of copper salts, which he recommended as a caustic to check bleeding and to form a scar.

277 See n. to Book II at 131 (1560).

278 The remainder of this sentence with the following two first appear in 1560.

279 "non respiret."

touches gashed warts with it, they will depart. When it is tasted, it impinges on the tongue like red-hot iron, but its use for drying up internal ulcers is to be discouraged unless they have been very foul, as occurs in some sufferers from a painless phthisis.[280] It contributes to the detaching of cancers and corrupted limbs, by a piece of olive wood smeared with it.

As I said, the [446]next topic is the remaining metallics mixed with juices, such as pyrites (ordinary people call it marcasite);[281] it is made up from stone and juice. It has almost as many kinds as the number of metals that are found. It is called pyrites because it is so hard that it emits fire when struck. It is usually of a silvery colour, bright; if it is sprinkled with sharp vinegar and ignited, it dissolves an excessively hard spleen as well as anything does. The explanation is the rarefaction and hotness of the parts,[282] which enters by the skin and peritoneum to rarefy the spleen. On its own it barely melts; on the addition of lead it dissolves, as happens to all the drier metallics; when the moistness is slight, or watery, if pyrites is put in the fire without lead, it is consumed away[283] before melting, but not when lead has been added. Hence when it has frozen, it needs to be melted by fire. The result is that when gold or silver are present in a stone, if they are melted with the addition of lead, the expense will not be wasted; if these things are &382 entrusted to fires on their own, something actually passes away, which can hardly be so small as not to exceed the waste[284] of the lead. Furthermore, in this pyrites there is one component that is unproductive, and another that contains metal (mostly copper) and is not unproductive—sometimes there is silver. The outcome of the unproductive kind is thought to be a vapour[285] rather than metallic matter; but it is agreed to come from a kind of metal; when it is mixed with lead, it makes rods to represent the tiny marks in printing.[286] In a slab of the whitest marble, I have seen such a quantity of golden[287] pyrites that the whole slab looked full of metal, to prevent you knowing from close up whether it was rather gold floating on stone, or stone on gold. It is usually extracted by crushing the stone, since pyrites is harder than marble, flint, or rock. It is also fragile,

[280] "phthoe."

[281] "Marchesita"—from an ancient Arab word for a form of iron sulphide. Agricola (cited by Nenci, 491 n. 118) said that the Moors used this word, not the ordinary people mentioned by Cardano here.

[282] Of the pyrites, presumably.

[283] "absumitur"; this word appears especially to indicate what is now termed "sublimation," in which a solid evaporates without previously melting.

[284] "iactura"—this word might possibly mean simply "cost" here.

[285] "halitus."

[286] "notularum pro typis virgulas": "notula" in late Latin is a little mark, and the rest is guesswork, assuming that type metal can be very good at filling the mould. An alloy of lead, tin, and antimony became customary as "type metal." The following ten sentences first appear in 1560.

[287] Reading "aureae" with *OO* instead of the "aure" of 1560 and Nenci.

being light. In fact these items are often associated, on account of their dryness. The white sort is purer, hence heavier. Some people therefore suppose that a part of the stone has been burnt up by the metal's vapour, and there is room for proof here; it actually originates on mountain tops; but its plentifulness shows that the metal is crude; and that the golden[288] material of copper[289] is featureless. These same items are formed at the time by the nature of the localities, with the descent of showers upon stones, and exhalation.

So take all these showers as together the cause of these items, and from their descent metals too, stones, plants, animals, and particularly fishes are generated, extracted by the exhalation and by the metals' power. Indeed, on mountain surfaces such things abound, coloured and burnt up, and with time they pass over into metal, and contain metal, being separated from the matrix.[290] Thus material of this sort is like a mole[291] in relation to a fetus, and like semen poured out on an alien site. Of this kind is Cisum,[292] midway between pyrites and Galena.[293] &383 Sometimes sory,[294] melanteria,[295] and chalcitis[296] blossom forth from pyrites, but Misy is one of these.[297] Melanteria is blacking, and of the vitriol kind, as mentioned. But the blue component in it shines marvellously. It is obvious that there is alum in shoemaker's blacking; if its clay is dissolved in water, the alum in it solidifies, and the blacking's oil emits the smell of alum. From pyrites and silver a kind of cadmia[298] is derived, which is called Cobalt. This is so corrosive that it burns the feet of the miners; the reason is the heat, which is considerable but medium. But if it were great, the stuff would be ejected, not dug out.

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[288] Reading "auream" with *OO* instead of the "aureum" of 1560 and Nenci.

[289] "aes."

[290] For Cardano's definition of "matrix" in a mineralogical context, see at 388 (1560): "a stone united with a metal is a matrix." "Matrix" essentially means a "womb."

[291] The "mole" here is evidently an abnormal mass of tissue formed in a womb.

[292] Nenci (495 n. 120) cites from Agricola the statement that the word "Kisum" [sic] is not Greek nor Latin, but "nostrum"—presumably German—and is *sui generis*. Its meaning is unclear.

[293] A mineral consisting of lead sulphide, and a main source for the metal.

[294] From the Greek σῶρι or σῶρυ: "a sulphide of copper or iron, probably marcasite," a word used by Pliny and Celsus (*OLD*).

[295] "shoemaker's black"— *OLD*.

[296] See n. 276 above.

[297] "at ex his Misy"; misy is a copper ore, probably copper pyrites (*OLD*).

[298] This is zinc oxide, calamine—*not* cadmium. Castelli has detail on it, distinguishing a native form with two kinds: one is cobalt, the other is devoid of metal and is "lapis calaminaris"; the manufactured kinds are varied and confusing. Crosland (*Historical Studies in the Language of Chemistry*, 107, 121) points out that Agricola used "cadmia" in various senses, and finally in the 18th century Macquer advised that "cobalt" should be used for one of the substances that had confusingly gone under that name.

But there is mild heat too in things that are mined, for instance in those that are mined in the so-called Joachimic[299] valley. Although such things are cold by nature, they appear hot when dug up, on account of bitumen or sulphur, or some sharp juice from their nature or that of lime.[300] In addition, sometimes you would say that in the form of pyrites nature had done battle with art as it does in the form of a die,[301] or sometimes of a cube too.[302] And there is a tawny one, which they call golden. Next to it comes antimony,[303] leaden in colour, with a shimmering brilliance, and scaly. A red oil is extracted from it, very pungent; the oil smells of sulphur, and retains sulphur's power. Antimony itself, as "stibium" is now called, has few uses, because of its thickness.[304] And as it is regarded as having a share of lead, so pyrites is regarded as having one of copper; this is why pyrites, as I said, shrinks the spleen. In fact pyrites appears to be the immature substance of copper, not its exhalation; in the Ocris mountains[305] near Tergestum[306] a pyrites mine extends so far and wide that if pyrites were an exhalation of copper, the whole mountain would have to consist of copper.

&384 But to return to Cadmia:[307] from it comes what when burnt smells—indeed, stinks—of garlic, like what is dug up at Annaeberg.[308] Cadmia itself is usually of a saffron colour, and thus very suitable for making aurichalcum.[309] Metals are present in metallics too, as silver sometimes is in antimony, and is only separable by fire. Antimony itself when smelted in a vessel passes over into some sort of lead, which can be called the fourth sort.[310] This is because antimony is the matter of lead, as pyrites is the matter of copper. Similarly, chrysocoll[311] is a kind of juice containing gold, from which it took its name. They come into being through some erosion by pungent waters: chrysocoll of gold,[312] and a

299 See n. 204 above.

300 "acrem aliquem succum de natura illorum aut calcis"—precarious syntax.

301 Singular of "dice."

302 The Latin adds "vel aleae," but since "alea" is synonymous with "tessera" which has appeared just before, I have not attempted to translate the phrase.

303 "stibium," στίμμι.

304 "crassitudo," which may mean density in present-day terms.

305 These mountains are in Albania near the lake of the same name (now Ohridsko).

306 Trieste.

307 See n. 298 above.

308 Annaberg, in Saxony in Germany (*Orbis Latinus*).

309 See n. to Book II at 106 (1560); probably a form of brass. There is further information in Book VI of the present work at 426–27 (1560).

310 The kind made from antimony is so called by Georgius Agricola, cited by Nenci (500 n. 129).

311 See n. just below.

312 See n. in Book II to 213 (1560) on chrysocoll. Here there is presumably a reference to the apparent derivation of the word "chrysocolla" from "gold" and "glue," i.e. a solder for gold, such as borax (though in fact malachite can be used for this purpose). But

blue thing[313] arise simultaneously, one (mostly the blue thing) overcoming the other, as Theophrastus records[314]—copperas[315] from copper, stygian waters[316] from orpiment.[317] Thus some are made from the matter of metals, others from the metals themselves; from the matter of metals we mentioned pyrites and antimony; from the eroded metals copperas, chalcitis,[318] chrysocoll and stygian water, misy, sory and such things. Things that erode are partly pungent, or salty, or acid; this same point can be examined in the crafts,[319] but the matter that is being eroded will be enough on its own; in fact copperas and chalcitis arise more genuinely from the matter of copper than from copper itself; the product of copper, as we shall show, is rather verdigris.[320]

Orpiment itself appears to have a share of gold, but the cost[321] exceeds the profit.[322] There are three kinds of it:[323] the native one is saffron yellow, and from that and salt is made the white one that they call arsenic. As this ages, it turns translucent, and this is the worst of all, and is called rosagallum. There is nothing to &385 prevent a similar product being made by the natural technique of mixture, but it cannot be the same, and because there are a number of kinds, one kind is not prevented from changing into the colour of another, since on account of the diversity of colour and moistness, colours in any single species can be altered by nature or by technical skill. In fact orpiment is changed to realgar[324] by fire, just as it is by nature, in colour—but not in substance. There is actually nothing to stop it being generated underground also, not as a [447]form[325] or as something completed,[326]

Caley and Richards (*Theophrastus on Stones*, 105) will have none of this identification of chrysocoll with borax for any period prior to Agricola, taking the view that he erred in his identification.

313 "Caeruleum"; on this see n. 418 below.

314 Nenci cites Agricola, who attributes this to Theophrastus, but I cannot trace it in Caley and Richards, *Theophrastus on Stones*.

315 See n. to Book II at 131 (1560).

316 On Stygian waters, see n. to Book II at 244 (1560).

317 See n. to Book II at 196 (1560).

318 See n. 276 above.

319 "artificiis."

320 "aerugo."

321 Of extracting the gold, presumably.

322 Pliny (*Nat. Hist.* 33. 79, cited by Nenci) recounts how the Emperor Caligula was greedy for gold, but got too little for his hopes.

323 The remainder of this sentence and the following six are modified in the different editions; see Nenci, 501 for details.

324 "Sandaracha," or sandaraca (*OLD*), already mentioned on 213 (1560) in Book II, is realgar or arsenic disulphide, and used to make a red pigment. Orpiment is the trisulphide.

325 "species."

326 "perfectum aliquid."

but as an item of waste. There are vivid colours in wastes, too, and such colours are also created by fire. So if some of them come into being underground by fiery heat, what prevents them being also made by the same procedure?[327] All of them, however, are immediate poisons; but among them croceum, which has kept its old name,[328] is more gentle. They are poisonous not only to human beings but also to plants and animals. Plants subjected to fumigation with them die. And not only mice, but even wolves that have eaten some of it and cannot drink water not only die, but are carried off into such rabies that they attack animals of their own species, and any they have bitten fall victim to the same rabies, so that the whole kind soon perish; I have sometimes tested this fact. But it is perilous to do so, in case you lose tame harmless animals, and in case they find water and you are frustrated. Truly, you will clear a house full of mice with a small thing, if it succeeds. With wolves it is harder, since they find water quite quickly. But poison is not in these alone; there is &386 orpiment in gold and silver, and there are the other dry things, such as antimony, verdigris, sulphur, on a basis opposite to the one on which lead is health-giving for them; they remove their moistness, so that they cannot readily be melted; but as the fire proceeds, since there is nothing to oppose that dryness, the substance of the metal gets burned, and passes over into smoke. And so they consume copper faster than gold and silver, but they also make these too vanish with an admixture of their fattiness. As they in fact possess a fat part which burns inside when mixed with metals, they drive the particular moistness of the metal into smoke; and when it is consumed, the metal itself vanishes, because it has no existence without that moistness. The big knots of trees do not burn on their own, but take fire when associated with added timber; in the same way, the moistness of gold and silver, unsuited on its own to burning, takes fire and is consumed when orpiment, sulphur, and the like are added. Among their kind therefore is the one that scrapes the skin off coinage, just as a snake often sheds its skin, with the shape[329] remaining.[330]

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327 "arte."

328 "Crocus of antimony" indicated an impure sulphide of antimony and sodium, so named on account of its brownish-yellow colour; no doubt this is the poisonous stuff referred to here. Crosland (*Historical Studies in the Language of Chemistry*, 71) points out that during the fifteenth century the term "crocus" was applied to yellow pigments generally.

Antimony preparations were used in medicine over many centuries, often as emetics; antimony could "purge" gold of contaminants, and so was thought capable of purging the body. Hence its preparations were manifestly not the most potent of "immediate poisons," though perhaps doing more harm than good.

329 "imago."

330 "Ex horum igitur genere est quod monetam decorticat, non secus ac serpens solet corticem amittere, manente imagine."—I can find no other meaning for "moneta" but the sense is obscure.

Returning to chrysocoll, which is now called Borax.[331] It is a manufactured kind, usually made from split alum and sal ammoniac. Galen[332] thinks it can even be made by diligently shaking a boy's urine in a brass mortar at the rise of the Dog Star.[333] The colour of the artificial product is a bright saffron yellow; goldsmiths use it to link pieces of gold, hence the name.[334]

But the blue or cyan stone which our people call Lazuli is very beautiful, sky-blue with golden spots glinting in between. Hence the thing's nature gives the craftsman a marvellous opportunity when it is chased[335]—it embellishes the &387 gold and represents clothing or stars. A suitable and well-marked stone should be selected, and the figure chased like a sculpture, not a hollow. Realgar[336] is what ordinary people call red orpiment, but it is not orpiment, it has a sulphurous smell, and the outside is saffron-yellow, not shining; the inside is red, shining, but the smell is not so unpleasant. It is on sale with a saffron-yellow look about the outside's colour and a mixture of orpiment.

Sidereal earth, which the Italians call "manganensis,"[337] is very suitable for purifying glass,[338] tinting it with a blue colour. There is another one they call "Zaphara,"[339] which imparts to glass a blue colour like this. And there is a green earth of a metallic kind, which the Italians call green "Azurrum," and we call "chlorogea."[340] It comes into being in productive mines of copper and silver, where it probably arises from a vapour[341] of copper and silver. It shines, and thus is very like the blue stone, but not of so much practical use. The blue stone's colour is not spoilt by fire nor by water, and barely by any length of time. Hence it is in high repute and costly. The reason is that it is very compact, and of very rarefied substance. Hence a limited quantity is enough for a large picture, as we will explain in connection with gold and silver too. The cause of the rarefaction and compactness is prolonged coction, and separation of useless components. This is why false blue stone[342] has almost no reputation; it is imported from Spain, but

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[331] See n. to Book II at 213 (1560).

[332] *De simplicium medicamentorum facultatibus*, 10. 15; K. 12: 286) refers to a product called chrysocoll by some, made by shaking children's urine.

[333] "sub caniculae ortu"—midsummer.

[334] "chrysocoll" = gold glue; "quasi auri colla," says Brasavola cited here by Nenci (504 n. 137), and see n. 312 above and n. in Book II at 213 (1560).

[335] Or "engraved"—"caelatur."

[336] "sandaraca"—see n. 324 on realgar.

[337] Manganese was not yet clearly singled out from magnesia; Castelli notes that Cesalpino and Libavius mention it, but says no more.

[338] Reading "vitro" with Nenci, though 1550, 1554, and 1560 all read "nitro" here.

[339] Castelli offers Zaphara = a mineral material from Bismuth.

[340] The identity of this mineral, here equated with "Azurrum," is not clear. It is mentioned again just below.

[341] "halitus."

[342] "pseudocaeruleus lapis."

is far inferior to the blue stone; not being as rarefied or compact, &388 more is needed for the job, and it has less resistance[343] to ageing, fire and water. But chlorogea[344] is still in repute, since its role is not a substitute but a principal one.

There are also earths mixed with metals—for instance Galena,[345] which the Italians call Ocria,[346] consists of lead and earth. Without doubt its matter is of imperfect lead, and so it is very suitable for the melting of metals, especially when they need extraction from a matrix[347]—a stone united with a metal is a matrix. Most of the nobler metals lie in stony matter, which can be called a matrix.

But among the metallics, none can be found more excellent than mercury;[348] people use cunning persistence to discover where it originates. Around dawn in April or May, in a clear sky, they look at the vapours rising in the mountains, and at a sort of cloud, not rising higher, but very insignificant, and sticking to the earth, so to speak. This is how the surveyors[349] reach the location[350] of the mercury there. It is very heavy and very rarefied, and as these two features were present in gold too, some people used to hope that the one could be made from the other. Look, not just among the metals, but among all the things I know so far; in it only gold sinks and moves down, while the rest float.[351] This same mercury not only absorbs gold, but also makes its way through deerskin, which is extremely thick. This is how the gold is separated: the mercury is warmed, and on it are put gilded pieces of clothing, or other items containing gold; and, as I said, soon the gold itself is &389 absorbed by the mercury; then the mercury is squeezed out with a skin, and the gold stays at the bottom; it is melted by a moderate fire and solidifies. There are other ways of collecting the gold, but not without acid[352] waters, or sulphur, and serious labour. Oil does not pass through a skin so quickly, so that mercury turns out to be even more rarefied than oil. It corrodes all metallic vessels, it perforates copper, silver, and lead, and so is kept more securely in wooden vessels than in metallic ones. The story is incredible, but one that anyone can confirm by experience, as I have. Hieronymus, described as

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343 The translation splits the "paruis" of 1560 into "par uis."

344 See n. 340 above.

345 See n. 293 above.

346 Nenci (506 n. 143) points out that none of Cardano's sources make this identification, which is not sound. Ochres in fact consist of fine clay with oxides of iron; Celsus (5. 14 and 5. 18. 19) commends ochre for making ulcers fill up. Pliny (*Nat. Hist.* 37. 179) refers to the "yellow ochre of Attica." See also n. to Book II at 213 (1560).

347 "matrix"—neither *OLD* nor *L&S* give a likely meaning, but the word is now defined here.

348 "argentum vivum."

349 "coniectores"—in classical times it meant "soothsayers."

350 "sedes."

351 This is true for silver and gold: the density of gold is 19.3, of mercury 13.6, of silver 10.5.

352 "acutis."

coming from Oculi,[353] used to tell me this on the evidence of his own eyes, but I could not believe it without personal experience. Certainly gold spread on mercury gets more fragile than eggshell, [448]so that it develops cracks of itself, and becomes quite like even the softest cement. When I had tried this out on a gold coronet[354] I broke it all into many pieces; that is why people who wear gold rings should take great care not to foul them with mercury. Its mere shadow exposes metals to damage, but gold much more so than silver. The reason must be that mercury makes its way in because of its subtlety, and compacts the metal through cold, so that it gets crumbly. The coldness of water reveals this effect on steel: if dipped often in it, steel gets so fragile that it breaks spontaneously, especially if the water is extremely cold. Touching mercury reveals that indeed it is extremely cold. So Moors, and the inhabitants of Africa, in search of a rest in the extreme heat there, fill a stone or wood vessel with mercury and &390 put a hide over it—then they lie on the hide.[355] If a test is done with iron as well, it will be a good idea.[356]

But why is gold practically alone in being broken, and more than any other metal? This is because it is almost alone, as we will show later, in being devoid of thicker fattiness; its moistness is very rarefied; what is very rarefied and minimally fat freezes very readily. Oil and all fatty things do solidify, but freeze very little. And therefore those who are keen to turn water into ice warm it up,[357] so that it gets more rarefied and freezes more easily.[358]

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353 This is Hieronymus Guerinus, a Milanese from Oculi, who is also mentioned in Book VII on 514 (1560). Cardano's *De Vita Propria* (cap. 15, *De amicis atque patronis*, 12) also refers to him, and says that he taught Cardano many secrets.

354 "coronatum"—not in any dictionary consulted, so the translation is a guess.

355 Nenci (509 n. 147) has traced this far-fetched tale to book 8 of Georgius Agricola's *De natura fossilium*.

356 The sense is not entirely clear. The following two paragraphs first appear in 1554.

357 "coquunt."

358 Aristotle (*Meteorologica*, 1. 12, 348b29–349a3; Loeb 85–87): "Hailstones do sometimes occur in late summer, as we have said. If water has been previously heated, this contributes to the rapidity with which it freezes; for it cools more quickly. Thus so many people when they want to cool water quickly first stand it in the sun." Note that Aristotle did not say that the previously heated water was still hotter than normal water when the cooling was started—only that it had previously been heated. This very old problem was discussed in *New Scientist* 2554 (3 June 2006): 10, and an explanation offered. Ordinary water, especially "hard" water, contains some salts, and salts that are present depress the freezing point and so make freezing take longer. Heating causes some of these salts to become insoluble and be precipitated; they are effectively no longer in the water. Thus the previously heated water may take less long to freeze than the normal water, on the assumption that both waters start their freezing at the same temperature. How far this is actually true remains at present to be explored.

Since the coldness of mercury can make its way through solids (it is lacking in substance), it freezes the moistness of gold. This is why gold is quite fragile; everything that is frozen can be fragile as well. This is demonstrated by ice, wood, fish, so much so that in intense cold weather people's limbs have dropped off whole.

But to return to the subject: Because of its heaviness,[359] mercury coalesces into one item,[360] in fact it makes for the bottom; it is usually single, which is why it coalesces into one item. It coalesces for another reason too: it is moist and fatty, and loses this characteristic on the way while on the move, which makes the transfer easier and more straightforward, one through which it moves along into a single item and a single location.[361] Being heavy and rounded, it has to move along in compliance with any cause, and very fast. Hence it hardly comes to rest, and gains its name[362] from that. So mercury is, so to speak, a metal not solidified; as ice is to water, so a metal is to mercury, and as ice does not disappear without melting,[363] metals do not do so before they liquefy. But being on its own a liquid like water, &391 mercury does disappear very fast; as water does when it vanishes,[364] for instance in distillations, it condenses afresh in the cold, and in the same way when mercury has vanished in a fire, it sticks to roofs and ceilings. Likewise, mercury and metals need less coldness than water and ice; excessive hotness is enough to prevent a metal solidifying, and water needs excessive cold to develop ice; similarly, water needs less heat than mercury to vanish.

Mercury is then a sort of condensed water — not condensed by heat, for it is not concentrated,[365] nor by cold, for then it would be a stone or a metal; but with its most rarefied and purest part earthy, which makes it very heavy, very cold, glittering, and liquid; it is a mixed thing rather than a solidified[366] one, since it is liquid, as I said.

Mercury is thus similar to water in four ways: each is very cold, and when it has vanished through heat, it returns to itself with cold. Each runs downhill, and coalesces into a rounded shape, taking flight from dryness. When they are amid dust and also in dryness, mercury and water get rounded; the reason is that they take flight from contact with dryness. But the portion[367] cannot touch another

359 "gravitas."

360 Presumably this refers to its droplet-forming tendency.

361 "sedem."

362 "argentum vivum": "lively silver" or "quicksilver."

363 But it does, in the everyday and long known but little noticed phenomenon of "sublimation," in which snow or ice evaporate in dry air without melting first.

364 I have hesitated to translate "evanescit" as "evaporate," since it is not clear here that Cardano reckoned that vapour was the result.

365 "cogitur."

366 "concretum."

367 "corpus."

one at any part less than a point; so mercury and water try to touch a dry thing at a point. This obviously occurs if they get rounded, since a sphere touches a plane only at a point. Therefore portions of water and mercury scattered onto a &392 dusty table will round up. But as large masses do not do this, nor become shaped into a cone pointing upward,[368] the indication is that this roundedness, in which the edges are suspended from the side, and a heavy thing is supported contrary to theory, is held together by sluggish moistness;[369] and consequently since mercury coalesces into larger spheres than water, and is also heavier, it must be very sluggish. It can be sprinkled like anything else, and in particles that stick together more slightly than oil,[370] which is evidence of sluggishness. Since mercury coalesces into a sphere, it creates a hatred of dryness, because the sluggishness is capable of persisting. And this is why particles of water preserve this roundness much less, since water is much less sluggish than mercury. But since water and mercury differ little and are of similar nature, this makes the mountains in which it arises both verdant and rich in springs. Through sluggishness it fouls gold and the other metals — or at any rate whitens them, if a gentler word appeals, so much so that it reveals itself as a sea bird[371] does.[372] I reckon it is worth while telling the tale of what has happened to me since I returned once more to my fatherland from the University.[373] I was being treated[374] in the home of the Nigroli;[375] they were armourers, not of common armour but of the kind that kings would search out. While I was staying there, I happened by chance to observe that a ring embellished with a hyacinth stone[376] that I used to wear on my index finger would quite often appear to have turned white. Noticing this, and unaware of the reason, had created a suspicion that I had received poison from someone; I had remembered &393 not handling such things. But I grew convinced that no harm was coming to me at the time. And in our town, even enormous jealousy does not get to such a level as to lead to destruction, but people pursue it by slanders, suspicions, disgrace, and false judgments. This is an

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368 "pronus" — the translation is a guess.

369 It is fascinating to watch the concept of surface tension being born!

370 "oleo tenuius haerentibus partibus."

371 A sea bird can reveal its presence by its droppings. The word "gavia" in the 1560 edition here (Nenci with *OO* reads "gravia") is rare but used by Pliny and Apuleius (*OLD*), and means a *tern*, a sea bird; splashes of mercury on gold might well resemble the droppings of a bird.

372 Material up to [A] on 395 (1560) first appears in 1554.

373 "Gymnasium." This episode does not appear to be described elsewhere by Cardano (in his autobiographical *De vita propria Liber*, posthumously published in 1643) or by his biographer Henry Morley, for example.

374 "medebar" — or possibly, "being comforted."

375 Nenci (412 n. 153) has located an account of this family in the reference work *Armi e armaioli d'Italia* (1940).

376 "hyacinthus"; see n. to Book II at 102 (1560).

excellent feature in our state, not to vent one's rage in murder because of jealousy alone. So while I am brooding on this, I notice that these patches can be washed out by water alone. Consequently I turned the cause over in my mind and kept suspecting that one of my patients had drunk mercury or sublimate.[377] While meditating on this, I notice as I leave the house that I have a whitened ring. I pay careful attention, I hear from my lad[378] that in that house mercury is sticking to the walls. At last I recognised by watching carefully that [449]gold gets defaced simply by passing through that house, in which metal helmets,[379] leather ones,[380] and other accoutrements of knights get gilded. I noticed this so often that I could not retain the least doubt. But one thing happened, a puzzling one in this situation: although I had five rings on my fingers, only one (or sometimes two) were becoming defaced—they were both on my index finger, one on the right one, one on the left. What I think was the cause was that they were in the uppermost part of the hand, and protected by nothing, so that they caught the heavy vapour on its way down; the others, which were on the smallest fingers, were protected by other fingers.

There could be another cause, since evidently the rings on the index fingers were of pure gold, while those on the other fingers were alloyed with "Smaltum."[381] It is thus agreed that mercury is of very rarefied &394 substance, and that those occupied in places where it is used are exposed to the diseases to which it gives rise; its thin vapour is drawn up to the brain through the nostrils, and brings about a tremor and paralysis,[382] and in relation to the lungs as well, it leads to phthisis. I realised this from the evidence, because I have seen many goldsmiths who used to handle mercury, I reckon about a hundred, become emaciated, and people decorating the hilts of swords with gold—and above all, those who I think were mixing verdigris and other metallic medicaments. Those who had a sturdier chest got paralysed through the weakening of their nerves, and others became tremulous, with the metallic vapour entering their nerves. It is agreed that after nerves are weakened and before they dry up, they are chilled rather then dried up, and this is as it should be,[383] for all metallics are cold, and

[377] "Corrosive sublimate" is mercuric chloride, intensely poisonous, and is so called because it "sublimes," i.e. it evaporates before melting.

[378] "puer."

[379] "cassides."

[380] "galeae."

[381] This word is not classical. Castelli offers "same as Amausum" and under "Amausum," "vulgo Schmalbglas," a readily fusible glass, used to burn pictures into rings—"encaustum." It has various colours. The word appears again later at 399 (1560) with the information that it is used to fill gaps in gold, presumably for decorative purposes.

[382] "resolutio."

[383] "id iure merito."

are stimulated only by the power of fire. The power of fire does not make its mark so rapidly that there is a conversion from cold into hot, unless there is a change of substance. This makes it clear, then, how dangerous it is to handle mercury, particularly along with fire, or to pass through places where it is being handled; granules stick to the walls, and gold is fouled on a sudden entry—and mercury regularly introduces huge disorders, ones of which hardly anyone is cured. It also makes women who use either it or sublimate lose their teeth, with cooling of the brain; the teeth that remain are scaly and black. The chest gets constricted, and foul-smelling gasping is produced. It is said that in the skull of a woman who had died two years before from distress in the head, without medical intervention, mercury was &395 found weighing two ounces. For myself, this is not so surprising as it seems; mercury was gradually being gathered in the brain, since she was using the cosmetic[384] daily, because of moistness which is combined with dryness. Mercury's power is then this, that it passes over into a very subtle vapour.[385] It would not be remarkable if anyone who has ingested it poisons rings with their breath, and is detected from this piece of evidence. Since it flows easily, and weakens nerves, it appears to be in potentiality moist rather than dry, but in actuality it is entirely like that. [A]It is reinforced by everything that removes its moistness; if, being moist and rarefied, it is fluid, it will be reinforced by everything that will dry that rarefied moistness. It will be strengthened by astringents, and by earthy things, so long as they get into it. So it is not hard to bring to a standstill,[386] because it would pass over into silver if it were brought to a standstill;[387] but since it is difficult to find something so rarefied as to be completely mixed with it, it is therefore solidified[388] by sulphur, because sulphur's very rarefied moistness burns. And it is solidified by the substance of metals, since it absorbs that substance, and by smoke; it is solidified by some things, and by some things too it is restrained through tenaciousness. This makes it no marvel if it is also strengthened by the juices of herbage. But it will come out no better. On the same basis, it is prevented from flowing by saliva, because of its sluggishness. Since, as we said, it is in fact sluggish on its own of itself, what is remarkable about its being restrained by another sluggish thing? But being solidified[389]

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[384] "Fuco"; on 398 (1560) below it becomes clear that this word refers to the use of a refined mercury product as a whitening cosmetic—but one with grave well-recognised toxic effects.

[385] "halitus."

[386] "sistitur."

[387] The reference is evidently to Cardano's usual term for mercury: "argentum vivum," or "lively silver," which on surrendering its liveliness through alchemical treatment would turn into silver proper.

[388] "cogitur."

[389] "cogi."

and being restrained[390] are different; whatever is solidified is restrained from movement—but not everything &396 restrained from movement is forthwith solidified. I call it "solidification" when it gets hard, which can hardly happen without admixture of sulphur[391] or some other body. But it is easily restrained, since this can occur with saliva on its own.

Then it kills trees because of its vast coldness and weight and power of corroding—slowly and not for certain, if it fails to reach the pith, but very fast and with certainty when it does reach it. The same mercury slaughters flies, fleas, bedbugs, and all insects, especially along with black soap.[392] There are people who deny that it and minium[393] were discovered long ago in the East. At Elbogano of Bohemia, the Scombach[394] vein of minium was discovered. But the price and importance it once had departed with the introduction of manufactured cinnabar.[395] There is another kind of cinnabar which arises naturally,[396] which need not be recalled now. But minium is very like realgar,[397] and no different from it, except that it drives out mercury, both on its own and still more so when heated with fire, and if the mercury is not separated, it absorbs it once more, as realgar does not set mercury free.[398] But we have mentioned above what sort of stuff realgar is. I would like to record this too about mercury, that when enclosed in a glass or stone vessel and unable to breathe, it bursts the vessel when a vigorous fire is applied, just as gunpowder does and on the same principle,[399] but with gentle heat it shakes it. So when a vessel containing mercury is inserted into a feverish

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390 "cohiberi."

391 Mercury reacts directly with sulphur when rubbed with it, producing the black mercury sulphide.

392 "sapo"; Castelli remarks that "barbers and children know what it is"!—and Galen mentions σάπων (*Methodus Medendi* 8. 4; K. 10: 569) as being "ex iis quae maxime detergere valeant." Castelli says the simplest recipe is animal fat ("sebum"), ash (which helps to explain why Cardano's "soap" was black), and salt. (But to make a proper soap, some alkali rather than salt would be needed.)

393 Just below, Cardano says that this resembles realgar (arsenic monosulphide, "sandarach"). In classical times, "minium" meant a red pigment such as cinnabar—see n. to Book II at 137 (1560)—or red lead (triplumbic tetroxide, still known as "minium"). Castelli is confusing on minium.

394 Schönbach might be referred to here, but is in Saxony, to the NW of Bohemia, where Elbogano lay.

395 See n. at 137 (1560) to Book II.

396 "nascitur."

397 "sandaracha"; see Book II at 213 (1560) and n. there.

398 "non mittente."

399 "ratione."

animal, the animal goes into agitated movement,[400] and ignorant people wonder what the reason is.[401]

So far, then, we have dealt with the nobler metallics that nature brings forth; but now let us see how far technical skill[402] can &397 emulate nature. Technical skill does have its own metallics, and metals too, also stones, such as myrrhina,[403] which we have covered already. So there are manufactured metallics: cinnabar,[404] sublimate of silver,[405] precipitate,[406] psoricum,[407] smaltum,[408] recrementum,[409] lapis diphryges,[410] cadmia,[411] pompholyx,[412] spodos,[413] flower of copper,[414] then

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400 "movetur."

401 "inde admiratio causam ignorantibus" (sic)—syntax elastic.

402 "ars."

403 Fluorspar; see nn. 39 and 45 above.

404 See n. to Book II at 137 (1560).

405 The word "sublimate" on 393 (1560) and n. 377 above refers to sublimate of *mercury*, and this must be what is intended here too: "argentum vivum sublimatum," not simply the text's "argentum sublimatum." Indeed, on the next page Cardano writes: "Argentum sublimatur hoc modo: *de vivo loquor* . . ."

406 "praecipitatum"; this is a mercury preparation, for which the procedure is specified just below.

407 This was a preparation for the relief of itching, mentioned by Celsus (6. 6. 31); the Loeb translation (2: 219 note *d*) adds that the composition was mentioned by Dioscorides and Pliny as including oxides of copper and zinc. There is a recipe for it in the present Book on 398 (1560) onward.

408 See n. 381 above.

409 The word used here ("recrementum") for "refuse" or "dross" is equated by Castelli with "excrementum." On 399 (1560) Cardano writes that it is "what is drawn off from a metal while it is being smelted; ordinary people call it foam. It retains the power and matter of the metal from which it comes; this is why dross from silver and gold gets smelted a second time, in case anything people are greedy for is lost." See below, 330.

410 Castelli is very specific about Diphryges: a kind of sediment from refined copper, settling and sticking to the bottom of the furnace. He would like it restored to medical use. *OLD* gives under "diphryges" "a slag formed in copper smelting," and Pliny (*Nat. Hist.* 34. 135–136) mentions various techniques for making it, and its use "to dry up moisture and remove excrescent growths and act as a detergent." Celsus (*De Medicina*, 5. 22. 2c) is similar.

411 See n. 298 above.

412 The Greek word πομφόλυξ means "a bubble"; in the present context, *OLD* calls it "a by-product from copper smelting, probably zinc oxide," citing Plin. *Nat. Hist.* 30. 106 (which says it is good for erysipelas) and 34. 128; Dioscorides (*De materia medica*, 5. 85) discusses medical uses of this.

413 σπόδος, mixed oxides of certain metals produced by calcination (*OLD*); Pliny (*Nat. Hist.* 34, 128–132) describes their preparation and uses.

414 "flos aeris," a scale or flake of the metal, produced by hammering it when heated (*OLD*).

slag, vermicularis,[415] stomoma,[416] rust,[417] caeruleum,[418] white lead,[419] sandix,[420] ochra,[421] plumbago,[422] silver foam,[423] purpurina,[424] glass. On cinnabar:[425] put sulphur in a jar, melt it, add twice as much mercury, keep mixing with it on the fire till no appearance[426] of mercury is visible. Then let it chill. Then heat it once more, and do it gradually till it does not creak.[427] Then you should smelt it over increased fires to the point that red smoke has come off. It does well for writing and painting with a red colour, and rivals native cinnabar.

[450]Argentum is sublimed in this fashion: I refer to "argentum vivum,"[428] and am not ashamed to use the barbarous name; but if you prefer Latin, it will be called "smelted silver," though this is not so clear. Put equal weights of mercury and cobbler's blacking into a mortar, and mix it with pungent white vinegar to the point that the mercury has stopped being visible; then smelt it in a glass vessel stopped up with clay till it solidifies. If any of it has slipped away and not coalesced, pound it again in the mortar with more vinegar, and smelt it once more.[429]

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[415] On vermicularis see 401 (1560) below.

[416] Cardano defines this in this Book on 400 (1560) as iron scale ("ferri squama"). Castelli equates it with "ferrum purgativum," and steel; and *OLD* with "fine scales obtained by hammering metals."

[417] "ferrugo."

[418] *OLD*: "azurite." Pliny (*Nat. Hist.* 33. 158 and 161; the latter section says that caeruleum is a sand, and discusses types from various sources) mentions it. Caley and Richards (*Theophrastus on Stones*, 183–87) point out that in the third century B.C., in the time of Theophrastus, there were only three stable blue pigments available: lapis lazuli, azurite, and an artificial one called "frit." They fully discuss their composition and sources.

[419] "cerussa"; see n. 119 above.

[420] A product derived from the burning of white lead; Castelli gives "cerussa usta."

[421] See n. 346 above.

[422] A lead ore.

[423] "argenti spuma," or litharge; the lead monoxide formed when air is blown over a molten silver-lead alloy (*OLD*).

[424] There is a recipe for this on 403 (1560) below: "It consists of equal parts of white lead ('plumbum album' this time) and mercury, and in addition of sal ammoniac and sulphur equal parts, but the parts to be a sixth or a quarter of the previous ones. The salt and sulphur are finely ground, the white lead and mercury are mixed (since the white lead needs to reduced to very thin leaves). Everything is mixed in a glass vessel and distilled; and what is still at the bottom is called purpurina."

[425] "Cinnabaris seu cinabrium."

[426] "species."

[427] "strideat."

[428] I.e. mercury.

[429] The apparatus for sublimation is described in much detail by Biringuccio (*Pirotechnia* 9. 2, trans. Smith and Gnudi, 352–53).

Red smelted silver[430] made in the following way is called precipitate.[431] Take equal parts of alum and copperas;[432] then add one half more of salt than of either of these, distil &398 all of this using glass vessels; put one unit of weight[433] of this water and three of mercury in a glass vessel, and distil; then increase the fires and continue till the smoke and the vessel turn red and none of the water is left. Finally, break the vessel and collect the mercury, which you will now see coalescing like a stone. Pound this up[434] very finely[435] on a porphyrite table, and smelt and distil it again in a glass vessel, till it dries. Breaking the vessel, collect the material left over once more, and pound it very finely[436] on the same table. Afterwards, put it back in a bronze vessel, put a strong fire under it, mix it with a bronze stick and stir for two hours, till it takes on nearly the brightness and redness of minium. Then take it out and store in glass vessels. If it is made aright, it is the best of all the agents that eat away flesh without causing pain, and dry up rotting viscera, and it has no other use that I know; similarly, people use smelted[437] silver[438] as a cosmetic;[439] it does whiten, and adds radiance to women's faces. It does loosen the teeth and produces foul breath.[440] But it contributes at many points to the usefulness of silver and the technical skill of goldsmiths.

Most metallics change their colour in response even to fire alone—for instance orpiment, which is of a low-grade citrus colour,[441] turns red when smelted in a glass vessel till it sticks to the vessel, turns red, and acquires the powers of precipitate—and the powers are not as much inferior as it is of more use for easy manufacture.[442] Psoricum consists of two parts of chalcitis,[443] and one of cadmia[444] or litharge.[445] These are mixed, and &399 pounded with pungent white vinegar, then buried at the time of the Dog Star[446] in horse dung for forty days. After being dug up, it is heated in a fresh pot with charcoal below, till it turns red.

430 A derivative of argentum vivum— mercury.
431 "praecipitatum."
432 On this see n. to Book II at 131 (1560).
433 "pondo unum."
434 "terito."
435 "tenuissimè."
436 "subtilissimè."
437 "excocto."
438 I.e. mercury.
439 "ad fucum."
440 "foetor oris."
441 "subcitrinus."
442 A very tortuous sentiment!
443 See n. 276 above.
444 See n. 298 above.
445 "argenti spuma," lead monoxide.
446 Midsummer.

Smaltum[447] is a sort of glass with which cavities in gold are filled up, and is of various colours and outstanding charm. It accepts all sorts of colours, and shines beautifully, and has no equal among alum and copperas and stony salt; other people mix the colours with glass.

Dross[448] is what is drawn off from a metal while it is being smelted; ordinary people call it foam. It retains the power and matter of the metal from which it comes; this is why dross from silver and gold gets smelted a second time, in case anything people are greedy for is lost. What does not melt when the metal does so is stone, and it too retains something of the metal, and the metal's powers. But in the case of the nobler metals, the stone is crushed and smelted. Diphryges[449] is made while the metal associated with copper is being burnt, and has the taste of copper, as is to be expected. When sprinkled with water it takes on a blue colour or that of copper; but if not sprinkled, it is purple or blackish. We said that cadmia[450] is native, but it is also created while a metal is being smelted, adhering to the furnace like a bunch of grapes. The best, arising from blue pyrites while it is in fragments, is shiny white, and what is whitest during grinding, since it is made from silver or even from gold.

Pompholyx[451] sticks on like a bubble while a metal is smelted, very like little brushes of wool.[452] Stick though it does to the walls, behind it there is still cadmia;[453] it is very shiny-white when it is very finely ground. It is called Tutia by common people. But the name "Tutia" also means "Spodos," since there is &400 little difference between Spodos and Pompholyx, as Spodon[454] is almost a sort of Pompholyx, or performs its function.[455] Pompholyx is less noble than Spodos, and each is of use for medicaments for the eyes. It is Spodos that sticks to the walls of second-grade[456] furnaces, in which metals are separated, and it solidifies in the smoke of gold, silver, and lead mixed with earth, which makes it less pure than Pompholyx, and weaker. It does not actually solidify, as Cadmia and Pompholyx do, out of the smoke and primary matter of metals, which is itself metallic, but merely from metal-free smoke and dust. Hence Cadmia and Pompholyx are found only in furnaces near mines, but Spodos usually in towns.

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[447] See n. 381 above.

[448] "recrementum."

[449] See n. 410 above.

[450] See n. 298 above.

[451] Previously mentioned on 397 (1560).

[452] "lanarum peniculis."

[453] See n. 298 above.

[454] The nominative case so spelled here, not "spodos," as it was earlier on.

[455] The word "Tutia" is not in *OLD* nor *L&S*; Castelli gives "vide pompholix; tutiae factitiae constructio legatur in *Theatrum Chymicum*."

[456] "secundus"—but this word might alternatively mean "successful."

Flower of copper is the water poured over copper while it is being extracted from the first furnace after firing. While it is being collected, it spits out granules very like copper, yet very easily reduced to dust on grinding. Scale is shed from copper while it is being hammered; what is shed by iron in the same way is called Stomoma—that is, scale of iron. Without intervention,[457] verdigris is scanty, but plentiful in the following way: put a scoured bronze vessel on top of another as a cover, and into the lower vessel (which can be of stone or wood or iron) put very pungent vinegar. In ten days you will draw off excellent verdigris from the bottom of the bronze vessel which you place on top as a lid. A large amount is obtained from larger and more numerous vessels and by repeating the process.

And as verdigris is obtained from bronze, rust is obtained from iron. Verdigris is not only astringent and drying, but also corrosive—similarly, rust is &401 more powerfully astringent and drying than verdigris, and free of corrosion. The particles in verdigris are in fact rarefied and sharper on account of their heat; in rust there is nothing hot nor rarefied, and hence its colour is not attractive.

So it is clear that among the metallics that are produced with fire, the colour resides in the more subtle substance, if it is not shiny black, and since rarefied substance cannot be mixed with compact[458] except through nature's favour, as has been shown, every colour (except shiny black) is labile.[459] But shiny black can hold its own,[460] being the deprivation of illumination residing in an earthy thing. So vermicularis[461] is closest to verdigris. After taking one part of white vinegar and two of old urine, mix them in a vessel of Cyprus copper, and stir with a pestle long enough for the ingredients to take on a rather more viscous[462] substance. Then add one part in each twenty four of salt and alum, and let stand in the sun for about forty [451]days while the Dog Star roasts the earth,[463] continually mixing and stirring. You will then have vermicularis from the start with the thickness of honey, but the colour of verdigris, yet much brighter. When it has been removed from the vessel and placed on a table and formed into the shape of worms (the origin of its name), it will even acquire the substance of verdigris.

Caeruleum[464] is made in the following way: pour three parts by weight of vinegar into an oak vessel, but first dissolve in it a quarter of an ounce of sal ammoniac of any sort; then tie onto a stick thin sheets of silver perforated with little holes and

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457 "casu."

458 "crassus."

459 "deciduus."

460 "consistere."

461 Nenci's n. 174 (529) cites a passage from Agricola (*De natura fossilium*, 9. 356) which describes the production of "vermicularis" in detail, much as Cardano describes it here.

462 "tenaciorem."

463 I.e. in midsummer.

464 "Azurite"; see n. 418 above.

smeared with mercury. &402 Hang the stick itself above the vessel so as to be near the vinegar but not touch it. Then cover everything over with warmish horse dung. After twenty days you are to extract the caeruleum from the silver and put it[465] back; and if necessary, smear the sheets of silver with mercury.[466] After another twenty days, scrape off the collection of caeruleum, throw it into a vessel smeared with silver foam (called litharge),[467] and bake it a little. Then wash it with chilled spring water, to get the powder off, and dry it in the Sun.

White lead[468] is made by putting pungent vinegar into a vessel. Then put on brushwood, and on the brushwood thin sheets of lead, weighing one pound.[469] Bury in horse dung. After twenty-five days you will collect white lead; or if you prefer to be a more careful guardian, after the first ten days scrape off the white lead, and put the sheets back, and repeat thrice. Another sort, very suitable as a cosmetic and very shiny white, is imported from Spain. Put thin sheets of shiny white lead (we call it "stannum")[470] into urine, and distil the whole of the urine; meantime the lead passes over into white lead, is dried, crushed and sieved.

From white lead sandix[471] is made, of a very fetching reddish colour. Place white lead, then, in an iron dish, and shake near a fire long enough for it to turn red and glow. It is thus evident that the best sandix ought to be made from the best white lead. Pale ochre arises as sandix does—hence Vergil's line:

> Of itself sandix will clothe the grazing lambs.[472,473]

But we are explaining manufactured[474] ochre. So smelt &403 black lead in a vessel long enough for it to acquire the colour of ochre; the colour of native ochre is flame-like. It is also made from reddish ochre,[475] when it is roasted in a vessel

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465 The silver, evidently.

466 "argento," but "argentum vivum" is meant, and is written by Georgius Agricola in the passage cited here by Nenci (530 n. 175).

467 See n. 445 above.

468 "cerussa."

469 "inde sarmenta impone, sarmentis plumbi tenues bracteas pondo unius."

470 See n. 155 above.

471 See n. 420 above.

472 *Eclogues* 4. 45. The spelling "sandyx" is now orthodox.

473 *OLD* quoting this passage calls sandyx either a red dye from oxides of lead and iron, or a scarlet cloth; it is not entirely clear what is meant here; Pliny (*Nat. Hist.* 35. 40) wrote that if "cerussa is mixed with red ochre in equal quantities and burnt, it produces sandyx or vermilion." Pliny thought Vergil believed sandyx was a herb, and Cardano followed him, but Vergil's words are not conclusive of this.

474 I.e. not native ochre.

475 Red ochre is a mixture of red ferric oxide with clay, sand, and other impurities. On its use in antiquity, see Caley and Richards, *Theophrastus on Stones*, 172–73.

smeared with dung. Silver foam, which we call litharge,[476] arises when lead is being separated from silver, and it is impure lead. And there is interchange from each[477] into the other. But litharge retains some power of silver, and the kind that is tawny-coloured is called "golden" for that reason. Plumbago itself arises from lead; when lead is attacked by fires, it passes over into these two, especially if linked to silver: litharge and plumbago. Plumbago has a certain slight brilliance, but is externally similar to litharge, and its lowest part of an ashy colour, its middle part of a mixed one. When it is reduced to powder, it turns out, so to speak, ruddy. Purpurina[478] is of a sandy colour, and if of high quality resembles gold. It differs only in this, that it is not resistant to the weather[479] and is not very long-lasting. It consists of equal parts of white lead[480] and mercury, and in addition of sal ammoniac and sulphur equal parts, but the parts to be a sixth or a quarter of the previous ones. The salt and sulphur are finely ground, the white lead and mercury are mixed (since the white lead needs to be reduced to very thin leaves). Everything is mixed in a glass vessel and distilled; and what is still at the bottom is called purpurina.

Every metallic matter that is manufactured by technical skill consists of two parts: one is rarefied and fiery, which usually burns, and is of a notable colour; the other is earthy and &404 excessively drying. The whole as put together is suitable for the conversion of metals; manufactured metallics are therefore prepared for three uses: for the healing of the human body, for painting, and for the counterfeiting of metals or gemstones. A fourth can be added, which is outside our brief: that is, for poisons.

After all these comes, by a considerable miracle, glass—a work of technical skill such as to resemble a gem's nature, and that is why it is extraordinary that when all these can separately be white, blue, black, purple, or green, glass can acquire all these at once. I recall once seeing a glass so choice in its brightness and the variety and permanence of its colours that it emulated an embossed agate.[481] Through extraordinary talent,[482] it is now picked out with white so subtly and methodically that you could say wax could not be worked more easily or subtly.

This is a unique instance of human frailty, which Princes as well as other people ought always to dwell upon, not only with their eyes but also with their

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[476] See n. 445 above.

[477] I.e. lead or silver.

[478] See n. 424 above.

[479] "non resistit iniuriis coeli."

[480] "plumbum album" this time.

[481] "Achates"; Caley and Richards (*Theophrastus on Stones,* 128–29) cite the descriptions of Pliny (*Nat. Hist.* 37. 139–141) and argue that the agate of the ancients was not synonymous with ours, though various varieties were so described both then and now. This sentence first appears in 1554.

[482] "miro ingenio."

mind; but human life is much more fragile than glass, and especially as it breaks of itself, while glass needs an external attack.[483] From glass are made organs with voices, musical instruments, with quite a pleasant sound, and ones that display a superior attitude to the beauty of the human kingdom.[484] Hence come attractive colours, a sweet voice, pleasing brightness, everything by slight mishap perishing in a moment. It is agreed that glass comes from three stones: clear (or sand), chali salt,[485] and starry. I remember setting forth their nature previously. All these are ground up and treated with a large fire in vessels, and are combined into glass by the fire's power; it is then &405 taken out into smaller vessels and smelted and worked in a furnace. But setting aside what is created by technical skill or is incomplete,[486] let us move on to more complete things.

[483] Translation precarious: "Principes perpetuò debent contemplari verùm fragilior est longè vitro vita humana, atque tantò, quantò res quae spontè frangitur, ea quae non nisi alieno impetu."

[484] "quae fastum pulchritudine humani regni ostendant"! It is possible Cardano is referring to something like the so-called glass harmonica here. It is not known when the resonation of glasses was first exploited in a "musical instrument," but the use of a glass to generate a musical note was discussed by Galileo in the "First Day" of his *Two New Sciences* (1638) in such a way that it was obviously a familiar phenomenon.

[485] See n. 264 above.

[486] "imperfecta."

[452] &405 Book VI
On Metals

What I call perfect[1] things are for example metals and stones; first we must deal with the metals. The metals are gold, silver, electrum,[2] copper,[3] Cyprian copper,[4] and lead, and iron. The manufactured[5] ones are steel, and tin,[6] and aurichalcum,[7] and in addition another one: Cyprian copper.[8] There are seven native metals, and four preternatural ones through the power of technical skill. Showing that this is the number and that no more are possible requires very great subtlety, but I shall show this; however, to begin with, I shall show that gold and the most perfect ones are found in the East, but iron in the West. It has been made abundantly clear already that the reason for this is that the East is hotter and wetter. It was essential to show that the East is hotter and wetter than the West; with that shown, it is evident that a better concoction and generation goes on there. Hence come what the Greeks call aromas and odours, and gemstones, and gold and silver, and all the delights of the human race; this occurs because the sea's vapour is carried from the East over the earth, and concocted[9] by the Sun's movement; in the West it is carried off towards the Ocean. &406 And if it were propelled by winds towards the earth, the Sun's motion would make it return quickly into the Ocean, otherwise it could not be concocted by the Sun's presence. An additional

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1 "perfecta."

2 An alloy of gold and silver in classical times, and is so still for Cardano; see just below at 407 (1560). It can however also mean "amber" (Crosland, *Historical Studies in the Language of Chemistry*, 102), as is confirmed by Cardano in the present Book VI at 426 (1560) below.

3 "aes."

4 "aes cyprium."

5 "factititia."

6 "stannum."

7 See n. on aurichalcum in Book II at 106 (1560).

8 It is difficult to differentiate this item, especially in an environment where (as Nenci observes, 537 n. 1) "white lead" is tin and "black lead" is lead.

9 "concoquitur."

point is that the Sun's motion imposes a similar power on the earth from its eternal rotation, so that the beginnings of things come from the East. These are the better and more welcome features, and so the Sun's morning rays delight us much more than its evening ones. But if the mountains are away from the West, the Sun's rays are full of moisture,[10] as are those of the stars and Moon, and fill the earth, and things that are getting too much burnt can hope for little good from the rays of sunset, the air being already very hot. On the other hand, mountains in the West keep the Sun away from the same direction, and what faces them burns, and these mountains are worse than a plain. It illuminates the earth in the East much earlier than in the West, because there are no mountains in the sea, but many in the land.

But let us now return to the number of metals. As we said, a metal is anything that is ductile and hard; wax and clay are ductile, but not hard; conversely, stones and pyrites are hard, but cannot be drawn out. Who will suppose that these seven accord with the number of the planets? The Sun could take gold, the Moon silver, Mercury electrum,[11] Mars iron, Saturn lead, Venus copper,[12] and Jupiter Cyprian copper. But it is better to list them like this: either a metal is wholly perfect, soft, and pure, and gold is like that; or it is pure, but hard, and silver is like that; or hard and impure, and iron is like that; or soft and impure, and lead is like that. &407 But electrum consists of gold and silver. Cyprian copper consists of copper and iron, hence it turns out harder than either, as does the product from copper and lead, for that too is harder then either,[13] and mules are sturdier than donkeys and horses. Copper itself is actually iron better concocted, and of stronger heat, so that sulphur smells more. The evidence is that iron passes over into copper. Agricola records that in the Carpathian mountain, at the town of Smolinitium[14] in Pannonia, as I have heard from others too, people had brought copper down with them miraculously,[15] and showed it to me, saying that a well exists from which water drawn up into three canals is poured out, and iron placed on them is turned into copper. But if the fragments were rarefied, they change

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[10] "humor."

[11] See also n. 2 above. As mentioned there, and just below in the text, this metal is an alloy of gold and silver. It is not obvious why the metal of the planet Mercury here is not to-day's "mercury"—which was to Cardano "lively silver," "argentum vivum." It was indeed mercury for astrologers such as those mentioned by Georgius Agricola (*De ortu et causis subterraneorum*, 5. 72–73, cited by Nenci. 539 n. 5), who allocated electrum to Jupiter, not to Mercury.

[12] "aes."

[13] On 429 (1560) below, Cardano remarks: "Cyprian copper is harder than ours; it is double, the native [sort] with gold patches showing through, as I have seen."

[14] Smolenice is a village in the west part of Slovakia, located about 60 km NE of the capital city Bratislava.

[15] "pro miraculo."

into clay, which when concocted by fires passes over into the purest copper. The reason is that iron and copper have the same matter. Hence iron passes over into copper when more fully concocted and impregnated.[16] There is a mountain near the well productive of stony copperas;[17] evidently, as we have seen, this power is present in copperas too.

And thus that so celebrated problem arose: can metals be transmuted into each other through the intervention[18] of technical skill? Before this is spelled out,[19] gold's superiority should be proved. Gold comes into being in many ways—firstly, mixed with sand, as in Bohemia, and near Bohemia in Ligis, in streams near Goldeburg[20] and Risegrundum, which in Latin is called the Valley of Giants, and on the bank of the Ticino and the Abdua[21] in Italy; next, also in stones productive of silver, as in the hill of Montisregium;[22] indeed, when the stones are melted, silver drips out, in each pound of which at least &408 half an ounce of gold lies hidden. Albertus[23] relates that gold is found in the most solid stones lying among burnt-out earth. He writes also that sometimes gold is found among the upper teeth of a human head, in the form of a very thin shaving—from which it is certain he believed that gold lay concealed in human hair.[24] I would have thought it probable that gold is generated among stones, and gets carried away from there by the power of running waters when it solidifies into little fragments, and is discovered among sand; and on the same basis it turns up when there is sedimentation between the teeth of a human head;[25] it stuck because bone is in the way, and because of the narrow gaps among their crevices. This view gains support[26] from what Gonzalo Ferdinando Oviedo the Spaniard[27] relates—that in the part of India called Peru, the gold found in the root of the mountains is imperfect, and the nearer it is to the mountain, the more

[16] "tingitur."

[17] On this see n. to 131 (1560) in Book II.

[18] "beneficium."

[19] "definiatur."

[20] In Silesia, about 50 m west of Breslau.

[21] The river Adda, which runs west near the north border of Italy into Lake Como.

[22] Agricola says it is in the Carpathians.

[23] Albertus Magnus; on him see n. at 2 (1560) in Book I.

[24] Nenci (542 n. 10) has identified the passage; Albertus held that inside the head was a "mineralis virtus" which emerged in the hair. But the gold that was found was not among the "upper teeth" of the skull in the ordinary sense, as Cardano writes here; Albertus wrote that it was in the "dentes suturae superioris cranei"—the interlocking saw-like edges of the skull bones meeting at the top of the skull, and very well placed to accommodate gold that would later emerge in the hair just above.

[25] Presumably a skull.

[26] "Astipulatur"; the word "astipulor" classically meant to support a person in an argument, but Cardano uses it in the sense of evidence supporting a view.

[27] See n. on Oviedus at 128 (1560) in Book II.

impure it is. It is not found in the depths of the earth either, but close to its surface; hence if it came into being in fields or in sand, it would lurk in the bottom of the earth.[28] There are coals[29] that originate in mountain summits [453]and are found underground at the root of the mountain; it is the same with gold. And for this reason it is commonly found in the beds of rivers among the rocks. Thus though the most valueless metals are hidden in the depths of the earth and are generally impure, nature is generous and (so to speak) prodigal of gold, and has made the very surface the location of this pure metal, shimmering with its own colour, and in no need of fires or technical skill. It is generated on mountain summits, usually mixed with a moderate amount of copper; this is confirmed by people who have written the account of the gold normally found in India.[30] When not fully developed,[31] it is very often carried down to the plains by rising &409 waters, and being of solid strong substance, it is concocted, developed, and brought to completion. At the same time, erosion by sand and stones or by earth carries off the actual copper and anything of no use. It is washed again by an influx of water, and so comes to glint amid the sand, and is generally gathered because of that feature. Its scarcity does not permit mountains to be easily excavated, the location being uncertain and too much interrupted by gaps, so that the whole mountain has to be excavated for a few pounds of gold, and even these would be consumed by the fire while we strove to extract it from stones. The river Adda[32] rises from Lake Como,[33] as the Ticino does from Verbanum;[34] both these rivers take in sands from the mountains that surround their lakes, and along with the sands, take in stones and gold; the gold is concocted at the bottom of the lakes, is perfected, and repurified. In this way, pure gold is generated by the Sun's power in the high points of mountains; it is generated mixed with other metals, especially among fragments of silver, as I said; metals are mingled together, gold in silver, copper in gold, silver usually with lead. But the gold that is mined along with other metals needs fire and a good deal of technical skill to get pure. Gold is also discovered — or rather is dislodged — from items the technique has made it adhere to; for instance from gilded vessels, also from clothing, as we explained above; in the same way, buried gold is excavated, and gold sunk in water is fished out. So there are thus three ways in which it can be gathered:

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[28] "In imo terrae"—but one would expect to read something like "just under the earth,"

[29] "carbones."

[30] On this see Oviedo, *West Indies*, 109, where he points out that the further from its mountain source the gold is obtained, the purer it is, evidently because of successive natural washings as it travels away. But he does not mention Peru.

[31] "immaturus."

[32] "Abdua."

[33] "Lacus Larius"; in fact the Adda runs into Lake Como.

[34] Lake Maggiore in northern Italy.

either by converting what was already in the open, and in a lump,[35] or by separating it from the other metals among which it lies hidden, or by gathering it pure. At the present time Italy does not gather pure gold, apart from a little that &410 I said was recently discovered between the sands of the Ticino and the Adda. At times even in Italy pure gold is dug up, by a copious interchange as I said: what is at the bottom reaches the surface. Then in Germany they dig up silver in some places, in wells nearly five hundred orgia[36] or paces deep. The size of nuggets of pure gold in our neighbourhoods and in Germany reaches that of a hazelnut, as it is found at times in Aldeburg[37] in the Carpathian mountains, and at the town of Slota. But if Gonzalo is reliable, in the part of India we have just mentioned[38] a chunk of obrizum[39] gold was dug up that amounted to 42 ¾ pounds. Four by weight is common, and sometimes even seven is reached, so great in those regions is nature's generosity, and the vigour and goodwill of the place.

But though they abound in gold, they also lack other metals, especially iron. Gold glints most of all metals, then silver. After it comes copper, then white lead,[40] electrum (less than gold but more than silver);[41] Cyprian copper quite slightly, and iron, then black lead,[42] and the rest of this kind. For glinting is the product of pure moistness, light and solid, in which the light is collected as it is in mirrors. No metal is translucent except crude silver of a red colour, and not always then; this sometimes resembles a carbuncle[43] in its colour and brightness, and people make something like minium out of it.

We must now show how this[44] comes to be the only one among the metals that is translucent, and why pure metals cannot be so. It becomes translucent when light and &411 illumination can pass through; air and water are things permeable to light and illumination. It is obvious that earth is not translucent; when it is in the mixture, it blocks translucency. And when moistness is burnt out, there is loss of translucency, because the earthiness escapes. So though oil

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35 "vel quod iam fuit in lucem, et massam."

36 Agricola, cited by Nenci (545 n. 16) with just the same words, spells the word "orgya." The Greek word ὄργυια means "the length of the outstretched arms, about 6 feet or 1 fathom"; ὄργυια is in Modern Greek a measure corresponding to two English yards, i.e. 1.83 m..

37 Altenburg in Saxony; Aldeberg to Agricola.

38 I.e. Peru.

39 Castelli mentions briefly that obrizum "est purum aurum, in spadiceum [chestnut] colorem arte calcinatum, aut pulveratum."

40 "album plumbum" here, not "cerussa."

41 On electrum, see nn. 2 and 11 above.

42 *Not* of course a synonym for graphite, a carbon product, but one of the metal lead.

43 "carbunculus." A carbuncle is a fiery-red precious stone, and the word also means "a live coal."

44 I.e. crude silver.

is translucent, when it is placed in a lamp it becomes opaque because of the soot which is mixed into it because of the burning going on.[45] All perfect metals are of watery and rarefied substance; they solidify with cold, as was said when we were dealing with ice, and they turn liquid with fire. Being liquid is a property of water alone among the elements. Added to the rest of the evidence that metallic substance is rarefied is this, that it is consumed by fires, and its notable earthy part vanishes with the wateriness. Besides, we are creating our evidence about the whole mass from one part of a mixed mass.[46] There may be an ounce of silver in a hundred pounds of lead, and though one may take evidence from a scruple[47] about the whole mass, as technicians do, the ounce of silver must be mixed throughout the hundred pounds of lead. So the 1200th part of a scruple of silver will also be evenly mixed in. This is the fiftieth part of one grain, so the metal has to be of extremely rarefied substance. There cannot be complete confidence in this test, since the mass was large; but if there is a moderate mistake, it cannot do any harm. And it is unsafe to make a test in costly items without using a larger weight.

There is also a third piece of evidence of the rarefied nature of metals: that two grains of iron or copper, mixed with gold so as to be &412 a little more than a fortieth part, alter its colour and hardness so much that you would almost say it was something different; pure gold glistens quite a lot, and is of a tawny colour, soft and very flexible. But with barely a fortieth part of iron mixed in, it gets stubborn, blackish, and with its brightness blunted. And so, if all metals are watery, they should also be rarefied or burnt up, or mixed with earth, since they are not translucent. Compactness[48] can be no obstacle, since diamond and crystal are compact and translucent. If then you have mixed a tiny part of dark opaque olive dregs[49] completely with much water, the water will turn red and stay translucent, but not so much so as it was before. And so, since silver is in itself black, as is obvious to those handling it, from the stain,[50] it does appear shiny white on account of solidity, like mirrors too, whose matter is black,[51] if it is mixed with watery humour, like watery olive dregs,[52] it will turn out [454]red and translucent, then glowing because of the glint of silver; and we call this mixture a

[45] "ignis."

[46] "tum quod ex una parte glebae mistae supra totam argumentum facimus."

[47] The twenty-fourth part of an ounce (*L&S*), and there are 576 grains to an ounce; Chapman (*How Heavy?* 82) offers 1.296 gram as the equivalent.

[48] "densitas."

[49] "amurca"—the watery residue after expression of the oil from olives.

[50] The stain it leaves behind.

[51] Nenci (550 n. 26) notes that Cardano diverges from his source, Georgius Agricola, in treating silver as black by nature, rather than the traditional white.

[52] "non secus ac olei amurca aquae rubrum evadet ac perspicuum"—but it is not clear what the role of "aquae" in the syntax is to be.

carbuncle[53] from the resemblance. A large quantity of olive dregs mixed with water ought not to turn red, but the water would be made opaque and black; in the same way, the role of silver is smaller and that of watery humour very large, if this kind of virgin[54] silver ought to be in large part translucent. But if it were either blackish or more plentiful than in proportion to the aqueous part, or impure, it will not be translucent. Quite enough has been said on why what is translucent has to be red, and on its constituents. Yes, and there is nothing to prevent other metallics derived from lead or copper being translucent, but this is a &413 rare event, because of their impurity; silver is in fact purer than copper and lead. Accordingly, on this basis it is possible to manufacture fake gemstones. But let us get on with what we had planned at the start.

Among stones, the following are translucent: magnesia,[55] slickenside,[56] specularis lapis,[57] flower of gypsum,[58] which Agricola considers differs from specularis lapis. There is something in each from the sorts of marble, but only phengites[59] is in general terms and completely penetrable by light. Numerous gemstones too are translucent, and indeed the whole kind of gemstones in large part, since many people believe that what is not translucent should not be called a gemstone. All the glasses too. Four among the juices: salt, alum, nitre, and tailors' blacking. No kind of earth is translucent; if one is mixed with much water, it would cease to be an earth—solidified by the moistness, it would be turned into a stone, and not be an earth any longer. Also, an earth cannot be translucent, because of its rarefaction; both nitre and gemstones, however translucent, when reduced to powder stop being translucent. So when an earth is not coherent but very rarefied, it cannot be translucent.

But I return to the account of gold. It alone among the metals exhales a slight good smell; silver comes next; copper is worst; the reason is the size of

53 "carbunculus." See n. 43 above.

54 "rudis."

55 A "scaly Magnesian stone" is mentioned in Book V at 369 (1560), and though *OLD* and *L&S* have nothing relevant, Castelli says that "magnesia" is commonly marcasite (Cardano writes "marcasite" as a word for pyrites; see n. in Book V at 381 [1560]), or liquid stannum, or a mix of silver and mercury, or other possibilities.

56 "'armatura,' this word means the bright shiny surface of fossil shells, either original nacre or replacing pyrite and marcasite" (Agricola, trans. Bandy, 226).

57 A transparent stone, mainly forms of mica or gypsum, used for windows etc. (*OLD*). The translators of Agricola (90–93) describe it as selenite, "gypsum occurring in transparent crystals," and Agricola treats of it at some length in that passage.

58 Gypsum is plaster of paris, and the "flower" usually indicates something developing on the surface. Castelli and *OLD* mention gypsum, but not the "flos."

59 *OLD*: φεγγίτης, perh. a kind of onyx marble (see Pliny *Nat. Hist.* 36. 163: "During Nero's principate there was discovered in Cappadocia a stone as hard as marble, white and, even where deep-yellow veins occurred, translucent . . . called 'phengites' or the 'Luminary Stone'").

the scorching heat. Because its substance is generated by pleasant heat, no nasty odour is left in gold; this is why its generation needs the passing of many years; all the rest of the metals are made more quickly. From a moderate heat the hardness that develops must be slight, which is why &414 gold is soft, and everything that smells good will be soft, as amber[60] is. And if geodes from Meissen (which people mistakenly call aetites, because in it another stone is in evidence)[61], [62] smells of violets, and stone of Berningerium and fragments of Aldenberg stone appear to smell good, they pick this up from the moss surrounding them; it is barely possible for their substance, or that of the other two, to smell good, for the reason we have explained above too.

Then silver comes second to very thin gold, a fact discovered by a test.[63] A denarius or scruple,[64] 24 grains of silver, is drawn out into a filament of 134 feet; these are about a hundred brachia of our units. Incredible it is to relate, yet all the craftsmen know it: a third part of one grain of gold can surround the whole of this; for two ounces of gold are spread over twelve and a half pounds of silver.

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[60] "ambra."

[61] "resonet"—this word normally means "resound, re-echo, ring."

[62] Pliny (*Nat. Hist.* 36. 140) says the name "geode" is given on account of its earthy character, and it is good in eyesalves and for disease of breasts and testicles. Castelli refers to Galen (*De simpl. Facult.* 9. 17; K. 12: 206), and Paulus Aegina; Paulus (7 cap. 3) says that "the Geodes is said to be considerably desiccative, so as to cure inflammatory swellings," and Adams (3: 226) remarks that it "contains iron, argil, and silica. It is nearly allied to the Eagle stone, and hence it is often called the Bastard Eagle-stone. Dioscorides recommends it as an ophthalmic remedy, and as a liniment for inflammation of the mammae and testicles. (5. 168) Avicenna says the vapour of vinegar in which it is dissolved checks the flow of blood and cures hot apostemes (2. 2. 398)." On *aetites*, Adams, commenting on Paulus Aegineta (who does not apparently himself use this word), writes (3: 227): "The Aetites, or Eagle-stone, is a species of oxide of iron. Dr Hill remarks that custom has given the name of aetites to every fossil that has a loose nucleus within it. The ancients used it very frequently as an amulet and incantation (see particularly Dioscorides and Aëtius). The Arabians also confirm, in the strongest terms, the imaginary efficacy of the Eagle-stone when used as an amulet. That it accelerated the delivery of women in tedious labours, Serapion and Rhazes declare, from ample experience, and that it would produce this beneficial effect on those who had faith in it *we* can readily believe. Indeed, we have often regretted that such innocent modes of working upon the imagination of women in labour had given place to more dangerous methods of practice in such cases. The Eagle-stone was retained in the English Dispensatory with all its ancient characters as late as Quincy." On this stone, Pliny (*Nat. Hist.* 36. 187) says that it is so named because of its colour resembling that of the white-tailed eagle. Agricola (*De natura fossilium*, trans. Bandy, 5, 102–3) discusses the geode (or gaeode) and aetites.

[63] This sentence, "Tenuissimum igitur aurum subsequitur argentum," could equally be read the other way round.

[64] See n. 47 above.

An ounce of silver into 3200 feet (or 2400 of our brachia), which are enclosed all round by six grains of gold.

That covers ductility. Equally worthy of admiration is the thinness gold possesses when it is beaten out with a hammer over leaves of silver: an ounce of gold covers eight of silver by weight. After they have passed across into leaves, you cannot find which is the thinner, gold or silver; thus gold must be a hundredfold thinner than the incomprehensible thinness of silver; hence it comes about that an ounce of gold can cover more than ten iugera[65] of land. This occurs because of the purity and prolonged concocting[66] of its substance; this is why people embellish carvings[67] of iron and steel with gold at modest expense, and the work costs &415 more than the gold. The reason is manifold, but I will set out three fairly easy methods.

Gold beaten into leaves[68] is mixed with mercury, then after heating on a fire it is poured into water; later, mercury is smeared on silver (if the vessel happens to be of silver); then the vessel is heated, and is combed[69] till it sticks everywhere. Then the mercury is removed by fire, and gold remains, sticking to the silver. If the gold needs to be united to copper or iron, you will do it like this: you will wash the vessel previously with wine in which have been dissolved sal ammoniac and verdigris in equal parts with a double portion of wine sediment; then after they have been dried, smear with mercury as before. Another method consists in water of separation, [70] of which I recall writing an account above. In a third method, leaves of gold are placed on red-hot iron, then on Spanish haematite with a colour of blood outside (from which it drew its name)[71] and of iron inside,

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[65] 1 iugerum = 240 by 120 Roman feet, hence about two-thirds of an acre (*OLD*), thus 10 iugera = 40,469 m^2. Starting from the statement (Taylor, *Chemistry*) that thinnest gold leaf is about .00008 m thick and that gold's density is 19.3 g, it appears that an ounce (27g) would cover a mere 17 m^2. Nenci too (553 n. 31) finds that Cardano's probable sources, Agricola and Albertus Magnus, indicate that gold leaf is not so thin nor extensible as he claims.

[66] "coctio."

[67] "caelaturas."

[68] "bracteas."

[69] "pectitur."

[70] "aqua separationis." On its preparation see Book II, 129–131 (1560).

[71] Haematite is mentioned by Jean Fernel in his *De Abditis Rerum Causis* (723; first publication 1548, two years before *De Subtilitate*), especially as good for red eyes; it is a red mineral (native ferric oxide), and hence good for haemorrhage and red eyes. The colour was regarded as a "signature," a sign from God, indicating in this case that the stone related in some way to blood. The word in this sense was originated by Paracelsus. See B. P. Copenhaver, "Did Science Have a Renaissance?" *Isis* 83 (1992): 387–407, and for an account of how plants might be thought to display characteristics suggesting their medicinal uses, see Arber, *Herbals*, 247–63. Earlier, Pliny (*Nat. Hist.* 36. 144) claims haematite as good for bloodshot eyes and excessive menstruation; with pomegranate juice

of such hardness that it hardly feels the file, to be rubbed down. This is not the soft German kind of haematite. It is thus clearly the Spanish kind, which arrests haemorrhage; it can be reduced to a very fine powder, and has outstanding drying and astringent power. When their task is frustrated, physicians use the German kind, which is no use at all. And so that stone[72] should be reduced to a fine powder, if the intention is to bring excellent help for the cure of blood-spitting. The physicians of our age are so blind, even in straightforward issues, that I have never noticed even one of them who followed the truth, since they are misled by resemblance of colour and substance.

&416 Moving on from the topics that are outside our aim, let us return to the subject. What they do with haematite they can do also with very light Ophys.[73] Thus the cause of all this is the vast ability to be thinned,[74] which gold has as its special privilege. Another feature is that it yields hardly at all to fire, unless it is combined with poisons; if it stays on its own or is molten along with lead in the fire for even twenty days, its diminution is not enough to be perceptible, though I would not dare to say there is none at all. One ought to learn the cause of this before anything else, and why gold does not stain. There are actually three features peculiar to gold: not to be consumed by fire, not to stain, and to be capable of extreme thinning. Fattiness does stain and burns, and it makes what is mixed with it burn; gold is alone in lacking fattiness. Also, things that are aqueous vanish when exposed to fire, but gold does not vanish in face of any fire. So either it does not consist of watery substance, or is held together[75] [455]by something. We have explained that every metal consists of watery substance, and therefore has an earthy admixture so thin and pure as to hold it together. But if this kind of thing were burnt, it would smell bad and burn easily; so, since it does not burn easily nor smell bad, that earthy stuff is pure and free of burning. So the characteristics of gold are to smell good, not to stain, not to be consumed by fire, to be very thin and very heavy, and very sluggish as well.

There is also a gold more perfect than gold, which is present in every kind not only of mortal things but of immortal things;[76] and I do not say it is purer, but it is more perfect. The purest &417 that is imported from India is in fact better

(also red), useful after a patient has brought up blood; also good for bladder trouble, and (with wine) for snakebite.

72 I.e. Spanish haematite.

73 This stone has not been identified, though ophites (*sic*; see n. in Book VII at 487 [1560]) is a sort of spotty marble, "serpentine."

74 "tenuitas."

75 "contineatur."

76 In view of their indestructibility, mercury and especially gold could be described as "immortal" in alchemical literature; for instance, van Helmont (1577–1644) in his collected writings edited by his son Franciscus Mercurius van Helmont (1618–1699) wrote of making mercury "as an Immortal thing, against any vigour and industry of Art and

than the purest that has been found elsewhere, and consequently than our ordinary gold. But the difference is not obvious, because any sort of gold is excellent. It is separated from silver with water of separation;[77] this melts the rest of the metals, the grains of gold pass down to the bottom of the vessel, and are collected from there and melted.[78] Another method: a mass comprising gold and silver is melted, and after its melting antimony or sulphur is added, and a twenty-fourth part of copper; then with the sulphur removed the pot is shaken three or four times. The gold passes down to the bottom because of its heaviness,[79] not being melted yet,[80] and then you will collect the gold by pouring off the silver. Silver melts more easily, because less compact; it is in fact much lighter than gold.

The gold is cleared of refuse in this way: it is hammered and reduced to wide thin leaves, then immersed in urine or vinegar in which sal ammoniac has been dissolved. Next, there is placed on the vessel a very fine dust comprising three parts of brick and one of salt. A leaf of gold is placed on top, then dust on the gold, and alternately in the same fashion till the vessel is filled. Then after a fire has been placed underneath for 24 hours, everything is taken out, the gold is melted, any silver present is kept among the ashes. When I said that the fire is placed underneath, I mean around too; if it is only placed below the vessel, the contents will be melted[81] with difficulty, or hardly at all. Gold is the consummation[82] of the metals and of the effort; silver comes close to it, so each usually lurks in every metal—I mean silver in lead, gold in copper, &418 but gold in silver; in fact the best part of silver is the gold itself. And so repurefied gold is the purest thing there is, of thin condensed watery substance, mixed with a very uncontaminated[83] earthy part, solidified by cold without fattiness, hence it melts without burning.

So I must try now to show whether it is possible to manufacture gold out of mercury or another metal, a point debated from the beginning. We must first see of what metals are composed. Because of their smell and substance, many people have supposed they consist of sulphur and mercury[84]—when they burn (especially copper), they smell of sulphur. And their matter much resembles mercury;

Fire, and transchanged it into the Virgin purity of Gold" (J.B. van Helmont, *Oriatrike*, 673–74).

77 On water of separation see n. 70 above.

78 Evidently to cast them into portions or bricks of convenient dimensions.

79 It is much heavier than silver—about 84 per cent.

80 Its melting point is 1064°C, while silver's is 961°C.

81 "dissolvetur."

82 "perfectio."

83 "syncerissimae."

84 Rhazes (al-Razi, 865–925) is credited with this theory: on him see L. Richter-Bernburg in *Medieval Islamic Civilization: An Encyclopedia* ed. Meri, 2: 671–74.

in colour it imitates lead and silver, in weight it imitates black lead[85] and gold. But out of two things already in existence a third cannot be made—so metals do not consist of sulphur and mercury. Also, in the places where metals are found, there is neither mercury nor sulphur; and where there is sulphur, there are crusted[86] mountains, and where there is silver,[87] green and happy ones, so that both cannot come into being in the same place.

But many people have thought that metals can be transmuted, because of the trial on copper already noticed above. They appear to change their colour and weight in response to fire, hence it is credible that they can change their substance too. And since some sorts of herbage get converted into each other, it should seem no marvel that metals can be transmuted. But this is not the way things are: either none of them, or anyway not all of them, can be transmuted into each other. In fact iron and copper, as both of them are &419 similar in weight and rarefaction and neither is resistant to fire, can be transmuted one into the other if they change their colour and hardness—either genuinely, or at least without obvious discrepancy.[88] None of the remaining metals can be turned into gold or silver; the only doubt is, whether silver can be turned into gold. I think it can, for what silver lacks so as to become gold is compactness (in this context it needs to get heavier) and colour, but these features can be added to a metal. If silver is made more compact, fattiness will be abolished, and it will be more fire-resistant and will (as I said) take on weight.[89] And so, since some of our friends boast that they have achieved this recently, one of two things is needed: that gold should be held within silver either in actuality or in potentiality. If in potentiality, generation will take place by fire—but it has been shown that fire generates nothing. Or if in actuality, why does the whole melt in water of separation, since it is accepted that gold does not dissolve in that? So it cannot be present inside in either way, except a tiny part in actuality, which though incapable of separation, is overwhelmed by the water and melted. So this gold is separated through the defeat of the silver by the fire, because something for completion[90] was lacking earlier.

However, so far as the other metals go, they cannot be transmuted into gold, nor into silver; these metals are already burnt up,[91] and what is burnt up cannot any longer revert to its original purity. There is also no transmutation of perfect

[85] As previously mentioned in n. 42, this is *not* graphite.

[86] "squalentes."

[87] The silver ("argentum") meant here is probably mercury ("argentum vivum"), but the editions do not support this emendation.

[88] "discrimen."

[89] The remainder of this paragraph first appears in 1554.

[90] "perfectionem."

[91] "exusta."

things that differ in kind[92] and nature; but gold is perfect and differs in kind from the other metals, since it is totally fire-resistant, and (as I said) &420 no other metal is not destroyed by fire, except silver. Once more: gold is extremely rarefied, and much more so than all the other metals (for the moment I am leaving out silver). Fire either compacts them by not separating them, or weakens them by separating them; neither of these helps with the generation of gold.

Also, as I said, gold is not vulnerable to fire, because it lacks fattiness; but fire is not required for separating fattiness present in some part of a metal; it is burnt by fire, and along with it so is the whole substance of the metal. Every metal is actually fatty, with gold the sole exception; I said this already earlier, in different words and rather obscurely, for every metal apart from gold fouls those who handle it, and is removed by fire.

Metals are made from the same matter as sulphur and mercury,[93] but sulphur from a more rarefied part of the matter, and it does [456]burn; mercury from the thickest[94] part, and one not much processed;[95] metals from a mixed matter and from a more temperate heat. And if a male and a female and a mole[96] originate from the same blood and in the same place, yet it is not necessary, nor indeed possible, for one of them to be generated from another. What is generated from them after they were begotten does not actually have to be interconvertible; hence too, if all metals are generated from the same substances, and mercury and sulphur are too, it is neither necessary nor possible for one to be made from another—unless maybe when both do not differ in kind[97] but only in their accidents, as was said in connection with copper and iron.

&421 Chemists can therefore alter colour and weight, but not subtlety and robustness.[98] Since testing for subtlety would be laborious and ambiguous, they chose to test gold by fire, and this is the reliable evidence on this issue. What is obvious is that if silver needs to be turned into gold, it should first be turned into clay, by an effective water; thereafter, the clay can pass over into gold.

Mercury appears to be closer to gold than to silver; it is like gold in its weight and its rarefaction, but to silver in its colour alone; it differs from both in being fluid, and it vanishes on the application of fire. This is why there are four

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92 "species."

93 Contrast what is written just above at 418 (1560): "metals do not consist of sulphur and mercury"; this appears to mean that a metal is not a mix of sulphur and mercury, but here Cardano states that it is derived from the same sort of [ultimate] matter.

94 "crassissima."

95 "elaboratus."

96 This is the abnormal "mole" sometimes formed in a human uterus, the word "mole" not being linked to the burrowing beast but to the word used here by Cardano and meaning a mass. See also Book V at 382 (1560).

97 "species."

98 "firmitas."

requirements for its turning into silver: for it to be solidified,[99] be made fire-resistant, be made lighter, and acquire a thicker substance. For mercury to be turned into gold, it has to be solidified, be made fire-resistant, and be tinted. Since these requirements are far easier than those for transmutation into silver, many people came to hope more for the transmutation of mercury (the Greeks call it "hydrargyrion") into gold than into silver. That celebrated drug-seller from Treviso[100] is thought to have achieved it—the man who in the presence of the Doge and wise men of the Venetian Republic transmuted mercury into gold, a miracle of which some traces still remain.

But however this came about, what is certain is that mercury cannot be transmuted into gold, much less into silver. Even though copper approaches gold in colour and lead does so in weight, still in its rarefaction of &422 substance and its purity and solidity,[101] silver is so like gold that the best silver is gold imperfect in substance and lacking in colour. This is why over long periods of time, if silver is pure it is partially converted to gold, as lead of great age is into silver. But if the seeds of silver are very precisely removed from copper or lead, silver will not be generated over any ages, nor gold from silver.

Then consider the friendly relationship[102] between metals: gold and silver love black lead,[103] and when they are melted they are mixed with lead; copper flees from lead, and both gold and silver consume white lead[104]—you may prefer to call it tin; so long as a reliable thing is set before one's eyes, the names you give it are optional. So when white lead is melted, in the furnace it floats on top of

[99] "firmetur."

[100] A town in Italy north of Venice. The "drug-seller" is probably Bernard of Treves (ca. 1406–1490), who was an itinerant enthusiast for alchemical transmutations, and of whom it is recorded that it "was resolved, at supper, that each alchymist present should contribute a certain sum towards raising forty-two marks of gold, which, in five days, it was confidently asserted by Master Henry, would increase, in his furnace, five fold. Bernard, being the richest man, contributed the lion's share, ten marks of gold, Master Henry five, and the others one or two a piece, except the dependants of Bernard, who were obliged to borrow their quota from their patron. The grand experiment was duly made; the golden marks were put into a crucible, with a quantity of salt, copperas, aquafortis, egg-shells, mercury, lead, and dung. The alchymists watched this precious mess with intense interest, expecting that it would agglomerate into one lump of pure gold. At the end of three weeks they gave up the trial, upon some excuse that the crucible was not strong enough, or that some necessary ingredient was wanting." http://www.everything2.com/index.pl?node_id=860351, accessed 15 Dec. 2007). He is also recorded in *DSB* (1: 22–23).

[101] "firmitas."

[102] "amicitia."

[103] "plumbum nigrum."

[104] "plumbum album."

the black lead and silver on a puckered wave, and in that form is usually removed with iron rods.

This is the more extraordinary because black lead floats on silver while molten, although it is heavier; and on that principle people pour off the lead floating on top, and collect the silver underlying it in vessels. The reason for this is that although lead is heavier than silver when solid, when it is melted it gets more rarefied, being ready to pass over into smoke, and keeps vanishing, although silver is not removed by fire, nor even thinned out; if it were, it would have to be completely removed. Accordingly, as lead's substance when the lead is melted lies midway between its own and that of smoke, but silver's is the same as &423 before its melting, it is no marvel that molten lead floats on top of molten silver. White lead, however, will float too, for a double reason:[105] it is removed by fire, and is lighter than black lead, so that it lies not only above silver but also above black lead. The separation of metals came to light in this way; the black lead is poured off when the white has already been removed, and the black takes with it the copper and iron, and is not poured off to the last drop,[106] to prevent the silver slipping out with it. Whatever is left of the lead after the bulk of it has been poured off is removed by fire. Then what remains is the silver, and any gold that is present mixed in the silver, because, as I said, it is separated by water of separation or else by the other arrangement[107] set out above. The lead that has been poured off is shaken out[108] afresh, in case it may contain any silver, and a corresponding amount of profit may get lost to the technician.

Copper is separated from lead, according to the correct teaching of Vannoccio Biringuccio of Siena in his "Pyrotechna,"[109] by placing the mass above an iron grid and surrounding it with fire; the lead easily melts and carries the gold and silver with it, if any of them sticks to the lead—and the copper is left behind "burnt"[110] amid the ashes. This is moved to stronger fires, and with the metal repurefied from its refuse, you collect it into a mass while still molten, and you will have very pure copper.

Most metals are also converted into water by some technical skill; they need to burn. They are more quickly and &424 conveniently burnt after the addition of orpiment, and when burnt and reduced to the appearance of lime, they are carefully dried; next, in a glass vessel very well closed, they are either buried for a period of a month three paces deep in earth moist, or hung for twenty-four hours above a vessel full of boiling water, with the water boiling all the time. It should be only two or three fingers from the water. It is likely that what was generated

105 "ratio."
106 "exquisitè."
107 "ratio."
108 "excutitur," meaning not obvious.
109 Nenci, 566 n. 51, cites the relevant passage from Biringuccio's *De la pirotechnia*.
110 "quasi adustum."

from the water returns into it, but gold and silver barely pass over into water, because of the solidity of their substance, as has been mentioned.

Silver turns up in three ways: either in earth, which surrenders it under the coercion of fire, or mixed with lead and copper, or in stones, which similarly release it when assailed by fire,[111] and also often mixed with copper, as in Alsace beside the Rhine, in the mountains of St Anna[112] and the Misnensian[113] ones; there are stones there impregnated with copper, and plenty of silver in the copper. Or it turns up pure in stones, and resembling a herb with twigs originating from the stone—I have a specimen.[114] As a [457]frequent event, I have seen trees—or rather, bushes—from the rough stuff which is imported from Germany and found there and in Bohemia at Albertami, and in Misena[115] at Annaeberg and Sueberg, so cleared of contamination that when its purity is investigated it only loses a tenth of its weight. Georgius Agricola records that in Bohemia a chunk[116] of silver was discovered weighing two talents.[117] This is a hundred and forty pounds by weight. Being pure when dug out, it reproduces various shapes: mattocks,[118] hammers, grids. &425 He says he saw the same kind of thing at Sneberg, which reproduced the shape of a statue of a man carrying a child. Silver is shaped by art, and is treated with copper, to such an extent that in many ways it misleads the eyes and the Lydian whetstone;[119] but describing two of these ways is enough for a sordid business. Place parts of equal weights of white orpiment or common arsenic and of saltpetre into a closed glass vessel, and let the whole be broken up for an hour on burning coals; take an ounce of this powder, the same of mercury and of dried wine sediment, and take half an ounce of it reduced to powder by the power of fire. Thus you then have two powders: the first, consisting of orpiment and saltpetre;[120] the second, which is made of that and mercury and wine sediment. Then when the copper has melted, add to each pound from half to one ounce of the original powder, until it is repurified by mixing; then after it has got purified, put in a quarter of the other powder; mix, and pour it

111 The remainder of this sentence first appears in 1554.

112 Probably the same as Annaberg in Saxony in Germany. .

113 Of Meissen, near Dresden in Saxony.

114 "quale apud me est."

115 Meissen: see n. 113 above.

116 "frustum."

117 The source (cited by Nenci, 569 n. 56) calls them "Ancient Attic" talents. These talents weighed about 25.558 lb = 26.3 kg each.

118 "ligones."

119 Cardano means "lapis Lydius," the Lydian touchstone, Pliny's phrase, but has written "cos Lydius," the Lydian whetstone. But (Plin. *Nat. Hist.* 33. 126) there is much of the whetstone about a touchstone, since the latter behaves like a file, and the expert can say from its appearance just how much gold, silver, and copper are in the ore scraped by the touchstone.

120 "sale nitro."

out at once into honey. There is also a quicker method with sublimed silver[121] and white lead. There are people like Pomponius Gauricus[122] who mix into each of two pounds of copper three ounces of each of saltpetre and arsenic, and concoct it.[123] For some people this turned out profitable, for others a punishment, since it is a base[124] for forged currency.

The practice of silvering articles is an art, and one endorsed by authorities and accepted by all honest people. Smear a jar with silver foam,[125] then rub thin leaves of silver with alum and salt and dry wine sediment on a whetstone, and put them in a vessel. Everything is melted together by fire and poured &426 into water. Carefully wash the article you want to silver first in vinegar in which sal ammoniac has been heated, and smear it with mercury or white lead, and add to it what you had already poured into water; finally, make the mercury or white lead blow off by applying fire.

Other people smear copper vessels inside with white lead so that they look silvered, which is a common practice with us; they do not give off a bitter taste, and are not so unhealthy, but rather nice to look at. They coat the vessel itself with black pitch, then they touch white lead with a red-hot iron; some of it sticks on, and they apply that at once to the pitch; the pitch is destroyed by the fire's vigour, and the lead adheres.

The nature of electrum is intermediate between gold and silver.[126] There are people who call amber electrum, but we are talking about the metal. The artificial and the native sort are different; the native kind's attractiveness and powers derive from gold with a fifth part of silver. If it has more silver, it does not stand up to the anvils. It is shaped into vessels for the sake of its beauty and usefulness; the kind that appears of itself reveals poisons in two ways: it squeaks, and it sends out rainbows.[127] No wonder, when tin and white lead and (more than all these) aurichalcum[128] take on a colour not their own simply through contact

[121] "argento sublimato": mercury.

[122] Pomponio Gaurico (1482–1530), writer from Salerno in southern Italy who wrote *De Sculptura liber*, "in impeccable Latin" (*Enciclopedia Italiana*), and a book of elegies. His authority in metallurgy is not obvious.

[123] "percoquant."

[124] "sedes."

[125] "argenti spuma," or litharge; the lead monoxide formed when air is blown over a molten silver-lead alloy (*OLD*).

[126] On electrum see nn. 2 and 11 above.

[127] Pliny (*Nat. Hist.* 33. 80–81) says that electrum is gold with a one fifth part of silver; and "Natural electrum also has the property of detecting poisons; for semicircles resembling rainbows run over the surface in poisoned goblets and emit a cracking noise like fire, and so advertise the presence of poison in a twofold manner." Agricola (cited by Nenci) copies the tale.

[128] See n. on aurichalcum in Book II at 106 (1560). It is also mentioned in the present Book (VI) at 405 (1560). Probably a form of brass.

with poisons, and suddenly lose their brightness. So while the rarefied moistness of electrum is being removed, it makes a squeak,[129] and by changing its colour a patch is seen to imitate the rainbow with a conspicuous sheen. Thus as wealth has its electrum, poverty has its &427 aurichalcum against poisons, because it brings their treachery to light. But wealth has lost the electrum that is mined;[130] though even now it can still be found, greedy eagerness and ignorance of its powers while people separate gold from silver have made electrum cease to exist. It is not such a great issue either for electrum to be altered by poisons (since even silver is spoilt), nor for hard substance to be affected by external poisons, since, as I have said, simply through contact gold is made so fragile by mercury.

Lead is, as I said, similar to silver. There are four kinds of it: the black, which is everyday; the white, which is lower-priced; the one that ordinary people usually call tin; and bismuth,[131] up to now unknown, a sort of intermediate between black and white. But it is not widely known even in our times, since it is only found in the mountains of the Suditis of Bohemia.[132] The fourth kind develops from antimony. All lead is thought to increase of itself, and so roofs collapse through their own heaviness. Galen[133] reports that when buried in damp places it grows in size and weight underground. White lead is different from tin, because white lead comes into being on its own, but tin is always accompanied by silver; tin resembles lead whitened with silver. All the metals hate white lead; adding even a hundredth part to gold and silver makes them fragile. Tin is also made artificially, and the more noble accepts one pound of black lead in 25 pounds of native tin or white lead. If a pound of black lead is mixed in nine pounds of white lead, it turns out hard, and excellent for making vessels. It is even approved &428 up to an eighth part of black lead being added—but if more is added, it gets worthless—the people of Milan call this pewter.[134] Tin used also to be made at one time from a mix of copper and lead. Tin squeals because it flows down from silver; white lead squeals too, and even tin artificially made. Hardness increases in tin, since black lead turns out harder because of white lead;[135] white lead is

[129] "stridor."

[130] "fossile."

[131] "bisemutum": not *L&S*; Castelli gives it as a spelling of bismuth, which there = marcasite.

[132] "Suditis Bohemiae"—perhaps the Sudeten area of the modern Czech Republic. Nenci (574 n. 65) cites Bermannus as thinking that Ptolemaeus used the name—which he did, but for a people living on the Baltic rather to the west of Danzig.

[133] *De simp. med. temp. et facult.* 9. 23; K. 12: 230.

[134] The "vulgar Latin" word "peltrum" used here became "peutre" in Old French, and "pewtre" in Middle English.

[135] It has just been explained that artificial tin consists of a little black lead in a lot of white lead.

less liable to cracks and to breaks, because of the softness of black lead and the substance with which it is filled up.

While we were writing this, a man at Milan used to wash his hands and face in public with molten lead, but he washed some of these parts first with some water. We should reflect on this, for he used to observe two preconditions for his manipulation: speed and water. In the water there should be some notable chilliness, and a manifest power, thick,[136] by which he would fend off the lead's heat and prevent it sticking to his body.[137] Some people say that this is achieved by the juice of the herb purslane, also that of the herb mercury, because of their sluggishness. Since I could see him using water quite sparingly, so that he sometimes let some part of his face get hurt, [458]I think it was rather a metallic that he used, such as antimony; there was plenty of profit, and on single occasions he used to collect no less than a gold piece of money, so that if it[138] had been gathered from such cheap[139] herbs, he would not have had to use it so sparingly.

Copper follows lead; in antiquity used not only for arms to protect people, and for shields, but it was also of use for spears.[140] And so Homer spoke of Menelaus with his bronze sword[141] in pursuit of Paris. It possesses a &429 permanent lasting quality in what it makes,[142] not being affected by rust as iron and steel are. There are actually three elements that give out moistness: earth, water, air; metals are damaged and produce rust from moistness; a thing that is safe from harm by moistness is safe too whether in the open air, or submerged in water, or buried underground. We showed previously that any matter that is burned more than the right amount[143] is protected from harm from moistness, as copper is, which gives evidence of exposure to fire only by the smell; so in fabrications copper needs to be everlasting, which is why I think in antiquity it was more highly valued than iron, not being worn away by time nor use. Nowadays, since stinginess rules the decision, people economize by using iron.

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136 "crassam."

137 Grafton (*Cardano's Cosmos*, 164) points out how Cardano includes instances of a mechanistic kind of natural magic, as here, reminiscent of the feats of the Renaissance engineers.

138 This "it," being of feminine gender, presumably must be either the *water* or (possibly) the "metallic," but the latter is improbable since the word for antimony is neuter.

139 Reading "vilibus" with 1550 and 1554, not the "delibus" of 1560, and in the next line, reading "debuerit" with 1550 and 1554, not the "vibuerit" of 1560; the final two letters of the two lines in 1560 have been transposed..

140 Syntax devious: "cuius usus antiquo tempore non solum ad arma quibus teguntur homines et clypeos, sed etiam lanceas utilis fuit."

141 The reference is to Iliad 3. 380, and here Cardano uses the Greek phrase ἔγχει χαλκείῳ.

142 "constructionibus."

143 "plus iusto."

The pipes of musical organs are made of copper—but some of white lead, some of wood. In this way you will hear in the same organ trumpets, horns, panpipes,[144] flutes, drums, the lyre, the tortoiseshell, the cithara in remarkable variety, and even other voices resounding in alternating ways. All that was missing was the human voice, which is as much harder to imitate as it is more charming than the rest. Copper is particularly suitable for trumpets, as it delivers Doric music[145] with a loud and lively sound, which is why it stirs men up for battle. Cyprian copper is harder than ours; it is double, the native sort with gold patches showing through, as I have seen. They say that in Hispania,[146] an island of the New World, a nugget weighing 200 pounds was found, alleged in different places to be of iron or of brass; a nugget grows to such a great mass. It is also dependent upon technical skill,[147] and is called cuprum because of the resemblance in sound.[148] &430 The more noble sort has one pound of white lead (which we call tin) in each four pounds of copper; and mixing in white lead up to an eighth part of the copper makes cuprum noble. But if aurichalcum is substituted for the white lead, it will be less valuable. If, as is often done to avoid expense, black lead is mixed with the copper instead of white, it will be very worthless. The use of cuprum is for large structures using fire,[149] for special glass vessels,[150] and for cauldrons. It is a great advantage in this copper that even without tin it does not taint victuals with any taste or smell.

Aurichalcum is also dependent on technical skill, and is ancient. Apollonius in the *Argonautica* wrote the following in Greek:

Λαμπετίη δ' ἐπὶ βουσὶν ὀρειχάλκειο φαεινοῦ,
πάλλεν ὀπιδέουσα καλαβρόπα.[151]

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[144] "fistulas."

[145] Music in the "Dorian mode" follows the sequence of intervals—whole tones or semitones—generated by the white keys of a piano from D upwards for an octave. It is the sequence that determines the mode, not the actual pitch of the notes. It is not immediately obvious why this should be particularly suitable for trumpets, although in fact (*New Grove Dictionary of Music and Musicians*, 2nd ed., 25: 831) the standard pitch for trumpets in Renaissance Germany and England was D, or E flat.

[146] This word appears to be a misprint here in the 1560 ed. for "Hispaniola" (now Haiti with the Dominican Republic), and also at Book VII 592 (1560) and Book XI 809 (1560).

[147] "Arte etiam constat."

[148] to "Cyprium," or "Cyprum" presumably; either form may be read at Plin. *Nat. Hist.* 36. 193 for copper.

[149] "machinas magnas igneas."

[150] "nolas"; Cardano explains in Book VIII on 569 (1560) that a "nola" is a "vas unicum tantùm vitreum," a unique vessel all of glass. The more ancient meaning is however "little bells."

[151] "Lampetie, in charge of the cattle, brandished a staff of glittering aurichalcum" (Apollonius Rhodius, *Argonautica*, 4. 973–974). Nenci notes that ὀρειχάλκειο should

He is referring to the times of the Argonauts, and calls it Orichalcum; Plautus calls it Aurichalcum, Caelius[152] relates that Aristotle said in his "Arcana" that aurichalcum or orichalcum was not mined anywhere.

But iron is mined on a contrary basis, and is not manufactured[153]—it is the most despised, the most respected, and is put equally to good and to bad uses. It softens in response to the juice of rinds of bean or mallow, if quenched in these instead of water. To make it ductile when it is being mined, the lump is roasted and put out in the open air; it softens with showers, because it is earthy. It is melted by the Sun because it is moist, and its sharper part, the part which is (so to speak) its poison, is melted by fires. While being roasted like this quite often, it is placed out in the open, and gets soft and as easy to handle as you wish. Also, if after firing threads of iron &431are allowed to cool down on their own, they turn out so ductile that you could use them for tying instead of string.[154] It is a good plan to have selected a thread at the start that is in itself soft and tenacious, the sort they say exists among the Swedes[155] of Germany, which they call Osemutum.[156] Soft iron is chased[157] in this fashion: what you want to represent is painted on the iron, facing it a ball of lead is placed underneath, then the part you want compressed is pounded with a small mallet. The part you want to protrude does not subside, being excluded by the lead. In this way people reproduce the shapes of animals and plants with subtlety, so that you could describe them as copied in wax and touched up with sharp knives. If iron is quenched in cold water while it is red hot, it must turn out not only hard but also hardly ductile, and fragile too; the fire within it is concentrated by the water's cold, and rapidly removes the innate moistness of the iron. With the departure of the ductility and hence of the softness, it has to get fragile and hard, which makes clear that nothing tenacious can be very hard. Gonzalo Fernández de Oviedo[158] in the seventh book of his work on *Indian Matters in the New World* (a distinguished author, and in my view truthful and learned, so much so that I regard him as the only historian of

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read ὀρειχάλκοιο. In addition, the Livrea edition of 1973 reads "ὀπηδέουσα καλαύροπα." The υ in καλαύροπα is correct; Cardano's β incorrectly represents an original digamma.

[152] On aurichalcum, see n. on aurichalcum at 106 (1560) in Book II. The Caelius here is presumably Caelius Aurelianus, physician around AD 420, who wrote *Acutae Passiones* and *Tardae Passiones*. But I have not identified the quotation here, nor the Aristotelian one just afterwards.

[153] "factitius."

[154] "linum"; *OLD* points out that the string is not necessarily made of flax.

[155] "Suedones."

[156] Georgius Agricola, cited here by Nenci (580 n. 79), mentioned that the Swedes used this word.

[157] "caelatur."

[158] See n. in Book II at 128 (1560).

our age worthy of inclusion with the ancients; his book[159] was given to me by the notable man Francisco Duarte the Spaniard, the Emperor's quaestor in Italy,[160] a patrician of unique humanity, justice, and prudence, and with a mind marvellously inclined towards learned people) reports that Indian captives cut their fetters with a thread of the herb Cabuia and sand, and thus plan to escape, and that this often happens in the island Hispaniola.[161] &432 If so, this Cabuia thread has to be tough, to stand much tugging, and be pulled quickly, and be broad and flat, to stop the sand jumping out; and the sand needs to be fine and rough and hard, similar to the Smirian stone[162] we will mention—iron will not be cut through in any other way. He reports the severing of anchors by this method; if quite hard stones are split by long and persistent and rapid pulling, what is remarkable about iron? This method is better than a file, because it is silent— hence there are muffled[163] files, which are thin and cut slowly without a sound.

Steel is more noble than iron—double: native and manufactured, and both very hard, and as I said, this is why it is more fragile than iron. The manufactured kind is made from the hardest iron repurefied, and marble.[164] The best, which shines with tiny glittering grains, is free of rust and cracks, and less heavy than iron. Admirably repurified, then made red-hot, quenched three or four times with radish juice and water of earthworms in equal measure, it splits iron like lead. Albertus Magnus[165] reports his own experience of this. This occurs (and experience of this still exists) [459]if steel is made excessively dry, hard, and thin by this medicament. Any steel like that can cut iron as if it were wood. Much more useful is my friend Galeaz Rubeus's[166] discovery, that an iron cuirass[167] would withstand a fiery missile. Technical skill can do so much—but when you have grasped the principle,[168] you will stop marvelling. The hardness is the same when the matter is the same, and it is sometimes stronger when it has been compacted, doubled and often made manifold—just as a bundle of &433 logs makes iron very tough. So iron, thin though it might be, when compacted by prolonged

[159] Nenci (21) indicates that this was the complete Spanish edition of the first part of Oviedo's work.

[160] Francisco Duarte, a Spanish military man who flourished in Italy about 1543–1552 (*Enciclopedia Universal Illustrada*). He is also mentioned in Book VII on 513 (1560).

[161] Oviedus (*West Indies*, 42–43) provides a detailed account of how this tough herb is used to cut metal. On Hispaniola, see n. in Book II at 127 (1560).

[162] Cardano has already mentioned this stone, in Book II; see n. at 131 (1560).

[163] "surdae."

[164] Crushed marble could be melted with the iron and assisted its purification.

[165] See P. Kibre, "The *Alkimia Minor* Ascribed to Albertus Magnus," *Isis* 32 (1940): 268-300.

[166] This man is also mentioned in Book I, at 45 (1560).

[167] "thorax."

[168] "ratio."

blows and the power of water, to the point where it consumes earthy and watery refuse under the influence of fire, must be rendered indestructible in the face of almost any blows, and always in the face of those of small artillery.[169]

There are very noble kinds of steel or iron, their cost exceeding that of gold for an equal weight: Agiambina,[170] Azimina Charmanina, Damascena, all of them having taken their name from the regions which are nowadays so called in our mother tongue. I am persuaded that a region contributes something beyond technical skill, by the fact that though steel was available throughout Italy, Germany, and Spain in Vergil's time, he still said, "But the naked Chalybes contribute iron."[171] So I would imagine that they are included among the above peoples.[172] Steel is corroded by the sea as much as iron, not just because of the power of salt, but also because of the tide and the winds—this can be seen on the latticed cuirasses, breastplates, and other armour of the island of Diomedea,[173] and nothing can correct this unless they are protected from vapour.

Iron[174] is purefied by technical skill and made noble, as Aristotle explains in his *Meteora*,[175] saying: Iron frequently concocted is purefied, and the earthiness in it passes over into slag, but the iron itself into steel. But the workmen[176] avoid

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[169] "parvarum machinarum."

[170] Scaliger (*Exercitatio* 107 [409]) remarks that he does not know who the "Agiambini" are, that everyone knows where Damascus is, that Ptolemy makes of Carmana a notable town in Arabia Felix, that Carama is a district of Persia, that Xenophon's *Anabasis* mentions Charmandem across the Euphrates, and much else in this confusing vein.

[171] *Georgics* 1. 58. The Chalybes were a people on the south coast of the Black Sea who were celebrated for their manufacture of steel (*OLD*).

[172] The remainder of this paragraph first appears in 1560.

[173] The Islands of Diomedes are now the Isole di Tremiti off the eastern coast of Italy, at about the same latitude as Rome. Diomedes, a Greek hero of the Trojan War, vanished on those islands leaving his armour behind, according to one account; see Brumble, *Myths* 103–4.

[174] This paragraph first appears in 1554.

[175] Aristotle, *Meteorologica*, 4. 6, 383a32–b5 (Loeb 323), cited by Nenci, runs: "Wrought iron will melt and grow soft, and then solidify again. And this is the way in which steel is made. For the dross sinks to the bottom and is removed from below, and by repeated subjection to this treatment the metal is purified and steel produced. They do not repeat the process often, however, because of the great wastage and loss of weight in the iron that is purified. But the better the quality of the iron, the smaller the amount of impurity." Lee's translation appends an informative detailed note about ancient iron making, which points out that then the fuel was charcoal, and could not attain the temperature at which iron melts—an achievement only adequately reached with the replacement of charcoal by coke in the eighteenth century. Before then, the product was really wrought iron rather than steel. However, there is in Porta's *Natural Magick* (1589) a description of steel production for swords, by a double quenching process (see Singer et al., *History of Technology*, 3: 35).

[176] "artifices."

this, because the more that departs into slag, the less iron is produced, and it weighs less. However, it is accepted that with a few additions, the transition into one of the above-mentioned very noble kinds goes on through this procedure.[177] For as it becomes purer and harder and lighter, it also turns out subtler, and &434 consequently more compact.[178] And doubly compact, different from lead, and different from bitter aloe,[179] but the same as iron.[180]

But over and above these there are manufactured kinds of metals, some less well-known, like the one made from two parts of silver and one of lead, excellent for making mirrors. Similarly, if gold is added to the three parts, better products of this sort emerge. And the thin leaves[181] that are put under gemstones consist of gold, silver, and copper, and are placed on top of live coals,[182] suspended so as not to touch, and thus they take on the brilliance of various colours from the varied proportions of their makeup.[183] Those that support a carbuncle[184] consist of copper and a one twenty-fourth part of gold, hence none are less long-lasting. Aurichalcum[185] too is the most noble, on a par with gold for beauty. Calamine stone or magnesia, silver, and Cyprian copper[186] (or plain copper[187] in its place, with glass added).[188] Glass is put on top, to stop the magnesia vanishing; and you will not rest content with having added glass and magnesia only once. At this point we put silver underneath instead of white lead, magnesia instead of cadmia,[189] Cyprian copper instead of common copper, and we repeat magnesia and glass. Vessels are made from these of exceptional usefulness, but are also made from all the metals—vessels that do not last long unguarded. They get

177 "arte."

178 "densius."

179 Agallochum, Ἀγάλλοχον. Paulus Aegineta (7. 3; trans. Adams, 3: 8–19) says it is "an Indian wood resembling the thyia, of an aromatic nature . . . the root cures waterbrash and loss of tone in the stomach, and agrees with hepatic, dysenteric and pleuritic complaints." Adams says it is not in Hippocrates nor Celsus, and gives other learned details. Castelli, *Lexicon* 23–24, also has details.

180 "Densum autem dupliciter, aliud ut plumbum, aliud autem ut agallochum, hoc autem ut ferrum"; meaning unclear.

181 "bracteae."

182 "prunis."

183 "ex varia illorum proportione."

184 The precious stone, presumably, not the "little coal."

185 On aurichalcum see n. in Book II at 106 (1560).

186 At 407 (1560) above, Cardano remarks that "Cyprian copper consists of copper and iron, hence it turns out harder than either," and at 429 that "Cyprian copper is harder than ours; it is double, the native [sort] with gold patches showing through, as I have seen."

187 "aes."

188 This sentence lacks a verb, like some others in the present work.

189 See n. in Book V at 383 (1560).

broken in three ways: fire melts them, and mercury perforates them and makes them fragile. They get bent when struck or squashed by a weight. When bent they develop a crack or are broken. To prevent their bending during washing, care is needed to see that a batch of three or four are washed together; when the first has been cleaned, the last is put in front of it; and thus by changing places, and all of them supporting the &435 pressure equally together, they all get scrubbed without being spoiled by bending. But if they have suffered a bend, it should be gradually corrected at once—like that they last forever.

[459] &435 Book VII
On Stones

The theory of metals has now been dealt with; we still have stones to discuss. There are five kinds of them in all: gemstone, marble, whetstone, flint, and rock. Over and above these, there are manufactured stones, about which we will speak when the account of natural things is complete. In common speech we call a gemstone every glittering stone that is by nature rare and small. The rarity condition excludes all the tiny stones on the shore; the smallness condition excludes marbles that glitter, and some kinds of these are rarely found, yet are not gemstones, not being small, but some of extraordinarily large size are found in each sort. We also said, "glitter": Limacius [1] and Borax are very small stones, and rare, but are not gemstones, and do not glitter—or if they do, they do not do it much. Along these lines gemstones include pearls, corals,[2] and turquoises,[3] and all the stones not originating in the East, such as carbuncle and German chrysolith, also Oriental topaz[4] too, and lapis lazuli[5]—but we have spoken above about this, as well as about emerald, and crystal too—though these hardly "feel the file,"[6] they are not real &436 gems; only those that do not feel the file at all are described as real gems. And for that reason all those we have just listed ought not to be truly

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[1] Cardano remarks later on, at 484 (1560): "Limacius stone is usually generated in the head of a snail, which is not covered over by a shell ['cortex']. As I can show, it ought to be of a shiny-white colour and a rough surface, because it has been congealed by cold out of watery substance, which leads to its being small, having been found in a small animal."

[2] The highly ornamental red coral is almost confined to the Mediterranean.

[3] "Turchesiae."

[4] "topazus"—"probably a kind of chrysolite" (*OLD*); in Plin. *Nat. Hist.* 37. 107 the translator renders this word as "peridot," a present-day word which Chambers defines as "olivine, a green olivine used in jewellery. Fr. *péridot*, origin unknown." See Cardano's later remarks on "piradotum" on 463 (1560).

[5] "caeruleus lapis."

[6] The phrase here ("limam sentire") is derived from Plin. *Nat. Hist.* 37. 109, and clearly means "to be marked by a file," instead of being so hard as to defy it.

named gemstones. So let these be called gemstone lookalikes; those that glitter and do not "feel the file" are gemstones; those that do feel it and glitter, and are not [460]small, are marbles in their whole kind. If they consist in flakes, they are flints; if in grains, whetstones; if none of these features is present, let them be called rocks.

There are three kinds of gemstones: translucent[7] like diamond, opaque like onyx[8] (as a rule), mixed like sardonyx and jasper;[9] some parts of these are translucent and some opaque. Others too present a reflected image[10] like a sapphire which I possess, and emerald, also the famous carbuncle found in Orchomenos in Arcadia.[11] The reason why gemstones present an image is primarily the glitter, then the hardness, thirdly the opacity, fourthly the dilute colour; in fact an image can hardly be presented along with a perfect colour. Gemstones are usually generated amid rocks, from the juice dripping down from the stones into hollows, as an infant makes use of the mother's blood.[12] In ferrous stones being ground down to make metallic vessels, we saw amethysts[13] and carbuncles, of the kind people call "granati," yet barely hard at all, because they were being exported from Germany.[14] So it seems that gemstones are generated from a purer metallic juice[15] among the stones—the more costly ones from gold and silver, the ignoble ones from copper and iron and lead. In our regions, then, noble gemstones do not come into being, because they are regions short of gold; and if they could abound in gold, the cold weather would be an obstacle. &437 Distinctions arise between stones and gemstones corresponding to the nature of metals: diamond corresponds to gold; carbuncle, emerald, opal, and sapphire to silver; carbuncle,[16] granatus, and amethyst to iron. As these last ones are not hard, we

[7] "perspicuum."

[8] Either a much-prized kind of marble, or a multicoloured gem, a variety of quartz (*OLD*). But it is also described as "a banded chalcedony in which the layers, alternately white and dark in colour, lie in planes one above the other" (Caley and Richards, *Theophrastus on Stones*, 127).

[9] "Iaspis"; meaning "various kinds of chalcedony, jasper" (*OLD*).

[10] "imaginem."

[11] Pliny (*Nat. Hist.* 37. 97) mentions carbuncles of unusually dark hue found at Orchomenos in Arcadia, and refers to Theophrastus as his authority.

[12] Apart from its final sentence, the remainder of this paragraph first appears in 1554.

[13] A purple variety of quartz.

[14] Presumably being ground down and exported because they were not fit as gems.

[15] This unexpected word may be explained by the Aristotelian theory of metals: "All these [metals] originate from the imprisonment of the vaporous exhalation in the earth, and especially in stones. Their dryness compresses it, and it congeals . . . Hence, they are water in a sense, and in a sense not . . ." (*Meteora* 3.6, 378a-b). And on this see Emerton, *Scientific Reinterpretation of Form*, 24.

[16] Carbuncle appears in two categories!

will call them juices henceforth, rather than gemstones. Though in its size and softness far removed from the nature of gemstones, crystal has the feature of arising without a metallic nature. Would you like an analogy[17] to the creation of gemstones? It is like knots in wood, glands in human beings, like some seeds in grasses, indeed more accurately like fungi in trees, and the more costly ones on the stems of roses. In fact what is liquid is condensed; what is rarefied and pure shines; what is impure only glitters; what has been long amid the rocks passes over into the hardness of stone. And it passes over into the hardness of a gemstone, because it is quite rarefied; it actually glitters, because it is flat[18] and solid; a very rarefied result is approached, especially if it is polished. So the origin of gemstones is like this, and that of the more costly ones is in hot regions, because the juice there is extremely rarefied. The result is that gemstones have the same amount of hardness as they have of glitter. Other gemstones develop in animals, as will be explained in the proper place.[19]

The gemstones that are generated amid stones do not turn up everywhere, but each separate gemstone has its own matrix.[20] Emerald is born to prassius,[21] and sometimes to jasper; jasper is born to flint. Carbuncle is said to be born to balassius,[22] crystal to marble, sard[23] to onyx,[24] like one I have, where you can see onyx manifesting itself at the bottom, sard at the top. &438 Gemstones are identified by touch, sight, use of a file, and substance. By touch, because they are heavier and colder than glass.[25] Hence the Indian nation are very cunning in distinguishing this kind; they regularly test gemstones by touch of tongue. The best ones are the coldest. Identification is also done by sight, because the brightness is more glittering, steadier, and more of an eyeful, and is not impaired by the light of a lamp as much as glass is. The substance is more lively and more light in

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17 "exemplum."

18 "aequale."

19 On 481 (1650) below.

20 "Matrix" means "womb."

21 See n. to Book IV at 318 (1560). This precious stone was sometimes identified as jasper, but clearly not by Cardano.

22 Nenci (590 n. 7) quotes Albertus Magnus as offering a derivation of this word from "palatius," on the basis that it is the home or palace of the carbuncle. *OLD* and *L&S* are silent on this; Castelli offers "Balasius seu Balassius" as a gemstone, purple or pink, akin to carbuncle.

23 "sarda"; Caley and Richards (*Theophrastus on Stones*, 122–23) cite Pliny (*Nat. Hist.* 37. 105–6) and Theophrastus to show that this signifies varieties of chalcedony suitable especially for seals. They are quartz-coloured, with a little ferric oxide. One variety of sard is now called carnelian, a bright red chalcedony of clear rich tint.

24 See n. 8 above.

25 Scaliger (*Exercitatio* 109 [414–16]) contests this, maintaining that the tendency to move up or down would be misinterpreted by a person hanging upside down. The following two sentences first appear in 1554.

weight. Identification is also done by file, because, as I said, they are not scraped away. The result is that in the places where they commonly are produced, gems are mostly brought to light during the day by the Sun's brightness; but at night, by that of the Moon or stars; some are sought and found by chance, others in excavated sites on reliable evidence.

Gemstones have many defects: some are of colour, like "smoke," "shadow," "small cloud"; others are of their body, such as "scurfiness,"[26] "hair," "salt," "point," "shavings," "plumbago,"[27] "rust," "redness," "abscess."[28] "Smoke" is darker, "small cloud" is more shiny white, "shadow" is more rarefied and blacker. "Hair" resembles erosion on the surface, so that the stone looks touched by a file. "Salt" is dimness inside—they call it ice. "Scurfiness" is a sort of roughness that draws its origin from the depths. "Point" is like a small bubble in the gemstone's body. "Shavings" is like scattered fragments. The brightness is damped down by "plumbago," and also by "rust" with a faint colour. "Abscess" looks like a deep compact pustule. I saw one recently like a tubercle,[29] since the outer surface was smooth, and the truffle[30] in the solid portion. It was remarkable, in that the inside appeared to protrude. You could hardly credit what it was, nor that it could be imitated by any skill.

Gemstones are not more subject to defects than animals or plants, but less; &439 however, faultless gemstones are less common than such animals and plants, because in gemstones their brightness and small size make defects more visible and worthy of notice. This is why we think that the majority of learned people are more exposed to rather serious failings, their sensitivity letting them down.[31] It is not really like that, but a distinguished name and modesty of form[32] make any failings more obvious and noticeable in them. But their obscurity protects common[33] people—they do not have so many human eyes directed at them as wise men do. In princes, high station[34] leads to a defect escaping notice, as a little stain does in a wide robe. The result is that the people get provided with a lever[35] for speaking ill of the wise. And the wise growing vexed in their turn, considerable ill will has been stirred up against their native land, from which often destruction and huge disasters stemmed. How much of a disadvantage, short of

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26 "scabrities."
27 Means "lead ore."
28 "vomica."
29 "tuberculum." The remainder of this paragraph first appears in 1554.
30 " tuber."
31 "sensu fallente."
32 "formae humilitatem."
33 "plebeios."
34 "magnitudo."
35 "ansa."

a divine judgment, was it to the Jews, that they killed Christ and James?[36] How much of a disadvantage to the Athenians that they killed Socrates? How much of a disadvantage to the Romans that they coerced Scipio Africanus[37] into voluntary exile?[38] But let us leave out the more obscure points—let us take the pattern from well-known ones. Pericles,[39] a man of enormous ability, charged by his competitors with having spent public money deposited with him, set out to avoid being compelled to present an account of this false accusation before hostile judges; by coaxing and persuading the people of Athens, he involved them in the Peloponnesian War, in which all their resources, public and private too, &440 were exhausted. The whole of their young people were carried off, partly by war, partly by plague along with the whole population. Fields were ravaged, cities were made subject to the power of Athens, razed, overthrown, and converted into colonies of their [461]enemies. Also, the Athenians lost their empire first, and then their liberty; in the end their walls were demolished, which was a major disaster, and the town itself was brought into the power of the Thirty Tyrants. Though it managed its politics to some extent scrupulously[40] and with some cleverness avenged itself on its enemies, it is clear to everyone that the state of Athens was never able to recover afterwards. The authority is Diodorus Siculus in the twelfth book of his collection.[41]

To return to my subject: brightness in gemstones and translucency[42] are what make defects more evident. The cause of translucency in gemstones (we

[36] This is St James the Greater, the brother of John and son of Zebedee, one of the original twelve disciples of Christ, who was beheaded in A.D. 44, under the orders of King Herod Agrippa, who was a Jew, and consequently the odium of his martyrdom attached to the Jews, as well as that of the Crucifixion.

[37] Publius Cornelius Scipio Africanus the Elder (236–183 B.C.) pursued a long and exceedingly distinguished military career on behalf of Rome against Carthage, culminating in the defeat of Hannibal, but ultimately he was accused of bribery and escaped trial by retiring into voluntary exile, dying the next year. Details in, for example, *OCD*.

[38] The remainder of this paragraph first appears in 1554.

[39] Pericles (c. 495–429 B.C.) was an aristocratic Athenian statesman and orator who played a leading part in the ultimately disastrous Peloponnesian War against Sparta and its allies. Before that War he had been charged with embezzlement, but presumably acquitted. Details in, for example, *OCD*.

[40] "nescio quàm sanctè."

[41] Diodorus Siculus flourished around 60 B.C. and wrote what he called his "Bibliotheca historica," a universal history in 60 books, of which only 15 survive fully. Nenci (594 n. 13) refers to 12. 38–58; this passage covers the long disaster for Athens, from the start of the Peloponnesian War to the Plague of Athens. See Loeb 4: 451–5: 49.

[42] Reading "perspicuitas causa" with 1550 and 1554 (though 1560, Nenci, and *OO* read "perspicuitatis causa"), because of the sense, and because there is an obvious explanation for the divergence: the words "perspicuitatis causa" appear correctly just below, and may have distracted a compositor.

dealt with metals above) is their lack of colour, and their possession of a watery substance. This is shown by experience of chalcedony, which is a kind of onyx;[43] when placed in water, it is translucent, and of a watery colour; when dried, it is shiny-white and barely translucent—it is of loose-knit[44] substance, which is why it absorbs water. By mixture with the water, opacity is removed; a shiny-white colour can never be perfectly translucent, since it scatters the rays, and alters them from their own nature, so that they cannot penetrate—or if they do, they cannot show an image of a thing with the colour spoilt. So a watery colour is present for these reasons—the colour that more than any other tallies with the translucency of water, glass, crystal, diamond.

Outstanding among gemstones are green emerald, &441 red carbuncle, shiny-white diamond, milky pearl, blue sapphire,[45] golden chrysolith, variegated opal. With us at present, their prices stand in that order, unless opal follows after emerald. To them hyacinth[46] is to be added, and prannium,[47] the one of a purple, the other of a matt black colour, though there is a considerable difference in price.

We have shown previously that all things that are mixed are alive;[48] this is especially appropriate for stones. They are not simply alive, but also undergo diseases, and old age, and later also death.[49] When worn out by old age, a

[43] See n. 8 above.

[44] "rarae."

[45] On sapphire, see n. on "select sapphire" in Book IV at 316 (1560).

[46] See n. to Book II at 102 (1560).

[47] This word is going to appear again on 472 (1560). Nenci here (595 n. 14) cites a comparable list by Agricola (*De natura fossilium*, 6: trans. Bandy, 147) which appears to be Cardano's source, but it does not include *prannium*. It does include *prasius*, which is further described by Agricola in the same Book (trans. Bandy, 127) as lighter in colour than beryl, and as named from its resemblance in colour to a leek (πράσον). It is now known as "prase," a leek-green quartz. Evidently Cardano has misread Agricola and "prase" should stand here and on 472 (1560). A stone called pra*m*nium is mentioned in a very similar context in a passage from Agricola (*De natura fossilium*, 6, trans. Bandy, 139) cited in Nenci, 637 n. 90—the same spelling as the name of the once celebrated Greek wine. But this seems to be quite different—a variety of the stone called "morion."

[48] "Vivere superius omnia quae miscentur demonstravimus." In Book V, Cardano remarks first on 345 (1560) that mountains have a species of life, as they consist of rocks, and then on 356 goes further and remarks that "all mixed things must be alive or have been so." Ficino (1433–1499), the Renaissance Platonist, had earlier taken the same view: "It may have been his analogy of cosmic to biological love which endeared to Ficino the notion (ultimately Stoic, also found in Plotinus) that everything—even stones, but especially the heavens—is alive . . ." (Ficino, *Three Books on Life*, Introduction, 29).

[49] Scaliger (*Exercitatio* 111 [416–18]) protests that diamonds do not deteriorate with age, and stones do not grow if cut.

lodestone[50] does not attract iron; it is weakened by dirt and filth, like an animal too. They do not in fact behave like this by quality, but by their life; pepper stops being pepper before what a person takes fails to warm him, even if it is very old pepper. But stones that are not decayed in any part are deprived of their own powers. All this is less obvious in stones than in plants, insofar as there is less life in them,[51] and the activities of life are less manifest. However, if you look, you will see them turn pale and dull, and be deprived of their own powers and undergo decay. And this is why after being excavated, stones continue to grow, since they are alive; even parts of plants, and crabs' claws, and lizards' tails are restored if torn off.

It will be quite in order[52] for someone to wonder why stones themselves appear to have greater powers than animals or plants, since animals and plants live with a more flamboyant[53] life. There are accordingly a number of reasons for this. The first is that while &442 animal and plant had to provide themselves with a life adapted to many functions, it was not practicable to temper the mixture enough to acquire these remarkable powers.[54] The evidence is that among the most worthless animals are some provided with more flamboyant[55] powers,[56] such as the salamander, silkworm, glow-worm,[57] chamaeleon. And among the stones it is not the gemstones that attract iron or point it toward the poles, but the dingy and unprepossessing lodestone. Another point is that soft matter could not support such power, nor could hard matter readily support a range of shapes; hence there are no leaves, flowers, or fruits on stones, or legs or eyes; and animals and plants do not possess such potent or extraordinary powers. In addition, the generation of stones takes a long time, but that of plants and animals a short time; and so nature can bring about[58] something greater with the aid of a long duration. Animals have more numerous powers, and as we take them to spring from voluntary decision, we are not astonished—or else we fail to notice them

[50] "Herculeus lapis." Scaliger (*Exercitatio* 102(5) [374]) scorns the thesis here that lodestones are alive and grow old—and die.

[51] "his," which should mean "the latter" but here surely means the stones.

[52] "meritò."

[53] "clarus."

[54] "vires."

[55] "clarus."

[56] "virtutes."

[57] "cicendula"; but "cicindela" is the classical spelling, in Pliny (see *OLD* for refs.).

[58] 1550 and 1554 and 1560 and Nenci all read "mo*ll*iri" ["to soften"] but surely "mo*l*iri" ["to perform, to bring about"] should be read.

because the animals are in captivity.[59] Hence it is possible to make an explicit judgment[60] about the powers of stones, yet not identify them.[61]

Men who have earned authority allocate profuse praise to the hyacinth stone;[62] among them is Serapio; in our *Commentary on the Art of Medicine*[63] we showed that he was Johannes Damascenus.[64] He held that hyacinth protects people who carry it about from lightning, so effectively that even wax which has been placed under the ornamental work on a hyacinth stone fends off lightning if it is carried about. This is also the experience in the regions where a number of people perish from lightning, since no one is touched by it who is carrying a hyacinth.[65] By a similar miracle, it delivers &443 those who carry it from the risk of plague, even if they live in pestilent air.

Its third strong point is that it procures sleep, and Albertus Magnus claims to have experienced this.[66] I usually wear a very big one, and it seems to help with sleep, but not much—however, this one of mine is not crimson and not of that excellent kind, but golden, and falling much short of the best. The best is actually the crimson, and is rarely bigger than a lentil. When it is near fire, that is, is placed on the live coals, it gets dimmer and more red, but when taken away from fire it starts glowing. Indeed, this kind differs little in distinction[67] from a carbuncle, since as I said, middling size is very rare. All the powers are manifestly linked to this kind, obscurely linked to the golden kind, not at all to the watery

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[59] Rather a shrewd remark!

[60] "apertè . . . iudicare."

[61] Rudwick (*Meaning of Fossils*, 20) points out that in contrast to a magical explanation, "Cardano accepted completely the virtues attributed to gemstones, but sought to give them a natural explanation in terms of their 'correspondence' with other entities."

[62] See n. to Book II at 102 (1560).

[63] *Commentaria in artem medicam*, probably written in 1546, and surviving only in a form too defective to merit inclusion in the *Opera omnia* (Maclean, *De libris propriis*, 81).

[64] There were an Elder and a Younger Serapion (as well as one before Christ). The elder was also known as Janus Damascenus, was often confused with Mesue and with the younger one, and was born in Damascus, perhaps in the 9th century, since Rhazes cites him. A *Pandects* by him in Latin translation (1479, called Aggregator or Breviarium) exists. The younger wrote a big *Liber de medicamentis simplicibus sive de temperamentis simplicium* (1531). He must have flourished after the end of 11th century. See *Biographisches Lexikon der hervorragenden Ärzte aller Zeiter und Völker*, 6 vols. (Vienna and Leipzig: Urban and Schwarzenberg, 1884–1886), 1: 167–68 (for Serapion the Elder) and 174 (for Serapion the Younger).

[65] Nenci (598 n. 18) cites Serapion (*De simplicium medicamentorum temperamentis*, cap. 388) for the key information that the stone protects its holder against thunderbolt, though not mentioning the wax.

[66] Nenci (598 n. 19) has identified the source in his works.

[67] "nobilitate."

kind—this is cheap and of feeble powers. In addition, hyacinth stone is thought to increase wealth and authority, to strengthen the heart to some extent, and to generate noteworthy happiness. We put these forward not as genuine results, but as possible ones. It is of a frigid temperament, a feature common to almost all gemstones, and suitable for the human spirit—either through resemblance of substance, or through illustriousness, or through a colour that is very similar, or through some other reason—it mends and strengthens it, and makes it cheerful; misery is simply contraction or shortage or dimness of the spirit.

From the same considerations,[68] as some people report they have found, it strengthens the heart better than anything; it fends off the plague, which strikes mainly through fear and through weakness of the heart, and &444 hyacinth abolishes both. This is why boys and women and [462]timid people are carried off very quickly by plague, but young men and bold people are not unless the plague is very aggressive. So it will help a lot to fend off the plague. Also, it will make people well-intentioned, because of their welcome and civilized cheerfulness of spirit; thus it will increase authority, and wealth too often grows in response to that increase.

One characteristic is left: protecting people from lightning.[69] This is no small service, since many distinguished men have perished from this so abrupt sort of death: Zoroaster king of the Bactrians,[70] Capaneus in the Theban War,[71] Ajax after the capture of Troy,[72] Anastasius the Emperor after twenty-seven years of

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[68] "eadem igitur ratione."

[69] The question of protection from lightning is also extensively addressed in Cardano's *De fulgure liber vnus*, *OO* 2: 721, and in Book II of the present work, at 100–102 (1560), and the n. on Ioannes Maria Cardanus at that place refers. The following sentence first appears in 1554.

[70] Of the place and date of the death of this mythical figure, not clearly distinguished from the prophet Zoroaster or Zarathustra, there appear to be diverse accounts. A prominent account relates that he was slain at the age of seventy-seven, at an unclear date when the town of Balkh (now in northern Afghanistan) was stormed. This account of the prophet's death is given by Firdausi, in his *Shahnama*, an epic poem completed in eastern Iran about 1,000 years ago.

[71] He was one of the "Seven Against Thebes" in the play of that name by Aeschylus, and while climbing on the walls of that town, boasting that not even Zeus could stop him, he was killed by a thunderbolt. (*OCD*)

[72] This is the "lesser" or Locrian Ajax, distinguished from Ajax son of Telamon. Both fought at Troy, and the distressing decease of the lesser Ajax is described in Vergil's *Aeneid* (1. 42–45); Athena smote him and his fleet sensationally with a thunderbolt.

his reign,[73] Carus too,[74] and also other Caesars. So let us explain in how many ways this can occur. Either it stops the lightning coming, or it shapes the purpose of the person carrying it, or it works because the only people who think of carrying hyacinth are those whom a thunderbolt would never harm, or it stops the hyacinth-carrier from being harmed even if a thunderbolt has touched him. I do not see how more ways will be worked out. To be touched by a thunderbolt but not hurt is hardly likely; and the people who write about it did not write "not be hurt," but "not be touched."[75] Furthermore, to stop the bolt even coming will be a greater miracle than this; anyway, great and conspicuous deeds are normally done by contact. That it was set up like this by fate looks very close to a fable. So it is better to say that the heart's gladdened spirit achieved this benefit, arousing a person to the point of being entirely safe from lightning. Saying that &445 even if he is touched, he is not hurt, is medical[76] and more natural, though very close to a manifest miracle.

We spoke on these points following Aristotle's practice, who thinks that in such tricky questions we do well enough if we avoid the more absurd mistakes. But for stones to protect us against accident, is like the story they tell about Erano, called the Turkish stone,[77] which is believed to sustain the whole injury if someone falls from a horse while wearing it as a ring—and even for it to be broken into pieces, the person being saved, has a less difficult cause, though a taxing[78] one—people add that it should be accepted as a gift. This stone is conspicuous for its sky colour, and glitters. It is proved[79] that it appears greenish by night, that the reverse side and the bottom is black, that it contains veins on the lower part, that it is smooth and not very cold, and finally that lime diluted and applied to it looks blue and takes on the gemstone's colour. And being like that, it is not translucent, nor is it a gemstone—it is scratched by a file. In addition, when put close to fire its colour blossoms, and droops and is dissipated by the moisture of hands alone. This creates doubt whether the tale of such virtue in the stone has been advertised at the jewellers' street,[80] to make a stone of high price but mod-

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[73] Anastasius I, Byzantine Emperor 491–518. But neither in the *Oxford Dictionary of Byzantium* nor in *OCD* nor in Gibbon is there any reference to his being struck by lightning. However, in Cardano's own *De fulgure* (*OO* 2: 720–36) there is an assertion to this effect, on 2: 721.

[74] Roman Emperor 282–283, but during a successful campaign against the Persians was struck by lightning in his tent (*OCD*).

[75] Reading "non tangi" with 1560 and *OO*, not the "non tangere" of 1580 and Nenci.

[76] "medicum."

[77] Or turquoise.

[78] "arduam."

[79] "probatur." This sentence first appears in 1554.

[80] "Seplasia gemmariorum": see n. to Book V at 354 (1560).

est and precarious beauty find buyers. And those with whom the tale[81] arose do not suppose it has powers other than those against poisoning and frenzy.[82] So if it can prevent injury to people falling, this would happen with a less hurried[83] person, which is why we are not endangered by lean and less valuable horses as they fall. But for the stone to receive the actual impact is incredible. Maybe it is so &446 soft that it is damaged more quickly while the horseman himself is falling. I have received an Erano[84] as a gift, and it has not happened to be tested, and my eagerness to know is not enough to make me want to test it. By a lesser miracle, they make the hyena stone and emerald predict the future, if they can do it;[85] I do not wish to discuss at the moment what it does, but what it can do, and why, and how. In the case of a gemstone worn in a ring or hung from one's neck (it is more powerful that way), or even held under the tongue (it can achieve most then), it reinforces one's forecast of what is to happen, and removes from the mind the view of what is not going to happen.[86] If you want to know how it does this, it does it in the same way as you attribute to your soul doing divination in a dream.[87] We have explained in our little book *De Animi Immortalitate* how divination by way of a dream happens.[88] And stones held under the tongue can create divination, by increasing judgment and prudence; divination is principally among these, as we have shown in the books *De Sapientia*.[89] People say that the breaking of an emerald sometimes during coitus has come to notice through experience.[90] Whatever the fact, emerald is the more fragile[91] of all gemstones. It is stressed[92] by heat and splits when concoction has been applied to plentiful and rarefied moistness; moistness when heated passes off into the air and takes up

[81] Or perhaps the stone.

[82] "lymphaticos."

[83] "minus presso"—the translation is a guess at the meaning.

[84] That is, a turquoise, as just mentioned.

[85] Nenci (601 n. 24) quotes Albertus Magnus, that the hiena (or hyena) stone was named after the animal, because its eyes could be turned to stone and removed, and when placed under a person's tongue, the stone enabled prophecy of the future.

[86] "confirmat rei venturae opinionem, non venturae autem ex animo delet."

[87] On Cardano's approach to dreams, see Siraisi, *The Clock and the Mirror*, chap. 8: "The Medicine of Dreams."

[88] Nenci (601 n. 25) has identified the passage in Cardano's *De immortalitate animi*, which briefly specifies the state of mind and body enabling divination.

[89] The passage in Cardano's *De Sapientia* identified by Nenci (601 n. 26) mentions as aids to divination an emerald, or the heart of a green frog, under the tongue, or a hoopoe's tongue round the neck.

[90] Albertus Magnus in a passage identified by Nenci (601 n. 27) mentions a mishap in his time, in which a King of Hungary broke an emerald on his finger during coitus with his wife.

[91] "fragilior," not "fragilissimus."

[92] "vexata."

less room, hence it disrupts things; this was stated previously. One's body warms up a good deal during sexual intercourse—we sometimes learn this from the breathing speeding up and the start of sweating. And this heat has more impact because it is not dissipated gradually as it is in exercises. When this gemstone is drunk, it strongly &447 resists poisons, since with its softness it is overcome by nature more than any other gemstone. With its translucency, the abundance of concocted moistness recreates[93] the substance of the spirit, contributes to human nature, and abates the nature of poison. Because it is a stone, it retains stable powers.[94]

There is also an emerald of the West Indies, named after rather an ancient province of Peru, quite hard, not very full-coloured, but of a fairly attractive appearance. When worn it seemed to me to produce grief, and dreams full of distress and fear. It is therefore suitable for unruly people[95]—it makes them more sensible,[96] and soothes their mind; on the other hand, hyacinth is more helpful for the gloomy and timid. Among the things that are attractive to look at, almost none is of no use to man. I refer to gemstones, gold, silver, silk, purple, so long as technique[97] does not pervert the appearance. So emerald with its beauty is the most outstanding of gemstones, as diamond is for hardness and solidity, sapphire for attractiveness, carbuncle for liveliness,[98] and opal for variety of brilliance, chrysolite for glitter, agate[99] for diversity; in the same way, emerald too contributes more to human good health. But, being very soft, it is particularly exposed to all accidents. It is spoilt by fire and heat; by contact with harder gemstones (especially with diamond); by steel, aurichalcum,[100] ordinary and Cyprian copper,[101] by impacts, by friction—in short, this gemstone is a prey to every injury, and this is why it is found on few fingers, being very expensive. [463]It[102] is greatly valued for its great brilliance, and is like &448 a kind of Sun, and by emulating woods and green meadows it fills the eyes with liveliness—there is no livelier gemstone. They say too that the best ones are ground with a Lydian whetstone and lose their coppery patch.

93 The translation follows Nenci in ignoring the colon present in 1560 after "recreat."

94 The following three sentences first appear in 1560.

95 "petulantibus."

96 "prudentiores."

97 "ars."

98 "alacritas."

99 "Achates"; Caley and Richards (*Theophrastus on Stones*, 128–29) cite the descriptions of Pliny (*Nat. Hist.* 37. 139–141) and argue that the agate of the ancients was not synonymous with ours, though various varieties were so described both then and now.

100 A form of brass; see n. to Book II at 106 (1560).

101 Cardano remarked in Book VI at 429 (1560) that "Cyprian copper is harder than ours; it is double, the native [sort] with gold patches showing through, as I have seen."

102 The remainder of this paragraph first appears in 1554.

It is agreed that to make moving dreams and pictures is far less extraordinary than offering divination. This stone I have about me thus makes pictures move busily in dreams, and reduces sleep, and increases memory. It is evident that it does this through the great dryness it has; its size is that of a pea, not a middling one or a little one, but a big one. Its colour is rusty at the top, with blood-coloured patches, with glitter, more hardness than that of an agate, at the bottom it is like turbid white of egg. These blood-coloured patches resemble a snail shell; where the stone is more shiny-white, there is what looks inside like a part of the internal coat of an egg.

They say that amethyst stimulates dreams for a similar reason, hence it is called "chala" in Hebrew, which means "to dream" on the evidence of Rabbi Ben Ezra.[103] Some gemstones stimulate dreams through a different conversion,[104] as onyx[105] does, whose common name is Nicolus; it alters and stirs the spirit; or others do it with beauty, as carbuncles, opals, and agate do. Some again do it by a property of their own. So it is clear that dreams are evoked by stones in four ways—and if they are evoked by causes other than stones too, these are easily reduced to the following four causes. Thus lying awake, when followed by a light sleep, makes moving pictures because of its dryness, and onions do, and cabbage,[106] and mustard, because of its vapours; also fear, joy, pleasure gardens,[107] love, because they stir the mind. And things that make movement[108] &449 spontaneously do, about which we spoke in the first book on dreams.[109] It is much easier to provide daring or alacrity, or even sloth, than to put dreams into motion. Again, arresting haemorrhage or strengthening the stomach, as we see jasper doing, should command almost no astonishment, since these can be attributed anyhow to the primary or secondary qualities. And these powers are in us. Furthermore, the substance of stones is hard, and the harder it is, the more it costs, as greater ductility does in the case of metals—thus gold is the most costly of the metals, and diamond is the most costly of gemstones on the basis of substance; for colour it comes second to carbuncle, opal, and emerald. This is a notable fea-

[103] Rabbi Ben Ezra (c. 1092–1167) worked in Islamic Spain and among other things, his writings introduced Islamic mathematics and Indian number systems to Europe. See http://www-history.mcs.st-andrews.ac.uk/Mathematicians/Ezra.html. Accessed on Feb. 8, 2008. Also see J. S. Ray, "Ibn Ezra, Abraham ben Meir," *Oxford Dictionary of the Middle Ages* 2: 835.

[104] "permutatio."

[105] See n. 8 above.

[106] "caulis"; can also mean lettuce.

[107] "viridaria."

[108] "movent."

[109] *Somniorum Synesiorum, omnis generis insomnia explicantes libri IIII* (written in 1535–1537 but published first in 1562: Maclean, *De libris propriis,* M34, 61).

ture of diamond, because even its fragments are expensive; a scruple[110] sells for six golden crowns; by its hardness it cuts all gemstones, and is not only useful but essential for chasing.[111] Diamond is so hard that it is hardly abraded and polished by anything except its own powder.[112] Its size rarely exceeds one ounce. This is borne out by one in Antwerp now valued at six million sesterces,[113] that is, a hundred and fifty thousand gold crowns, despite its being a scruple short of an ounce. When cut and polished, it is expected to fetch at least four golden talents as a rule,[114] although the effort is hardly worth half that.

People attribute to the same cause, as it has an obvious explanation,[115] the fact that a sharp point smeared with diamond dust, whether it is that of a spear or a pike[116] or a sword or an arrow, can pass through all armour, such as a cuirass and helmet; it &450 heats up the iron or steel with its impact, and penetrates the iron in its path. This is evidence of the utmost rarefaction[117] and hardness in diamond. Another feature of diamond is that when polished, of the gemstones it glints the most. A third feature is that it is fire-resistant, coming to no harm at all up to the ninth day, and even remaining undamaged for many days longer.[118] After it come carbuncle and granatus,[119] getting to the fifth day without harm, but they do not all do so, nor on every occasion. So after diamond, these are the least vulnerable to fire, and of extremely subtle parts—if they were not of very rarefied parts, they would accept pores through which fire would easily get in, as has been shown, and disperse them. The coldness itself too contributes to the rarefaction and solidity, so that these stones are extremely fire-resistant, with the result that a sapphire itself does not readily yield to fire, and is harder than a carbuncle, but is placed third in rank of the stones that are least vulnerable to harm from fire.

Suppose someone then asks: "In what respects does diamond differ from crystal, since both of them have a sheen and are of a shiny-white, or rather a watery, colour?" We will say that the sheen of diamond is lively and sturdy, so that it not only has a bright sheen, but glows and glitters; besides, it is immune to iron, moisture, fire, age, and use, characteristics all of which crystal lacks, since

[110] The twenty-fourth part of an ounce (*L&S*), and there are 576 grains to an ounce; Chapman (*How Heavy?* 82) offers 1.296 gram as the equivalent.

[111] "caelatura"—the jeweller's process.

[112] The following three sentences first appear in 1560.

[113] "sexagies sestertio" instead of "sestertium sexagies": see *OLD*.

[114] The phrase "ex more" here is not classical and the translation speculative.

[115] "ratio."

[116] "sarissa," σάρισα, used originally in the Macedonian phalanx.

[117] "tenuitas."

[118] Diamond burns "with great difficulty, and at a high temperature" (Taylor, *Chemistry*, 396).

[119] A type of carbuncle; see 426 (1560) above.

it ages very fast. Also, if it is warmed diamond attracts straws, just as amber does, but not very strikingly, because it is small.[120] When tied to the left arm so as to touch the flesh,[121] it suppresses night terrors, as I have often found. It is wrongly supposed not to be broken by impact, because a hammer reduces it to powder; in relation to impacts, it is &451 a little harder than crystal. But it does not stand in the way of a lodestone's attracting iron; these two features[122] have been wrongly atributed to it, and many a time revived even by young writers and published everywhere—all they show is the vast sluggishness and rashness of the writers; writing discordant[123] things that you have not tried out displays the utmost rashness, and not experiencing what you so easily could displays greater craziness. The green gemstones—not just emerald, but all the others, such as prassius[124] and topaz, are vulnerable to fire, and more than all the rest. The reason is their abundance of half-concocted humour;[125] as Aristotle says, metals are generated from a moist exhalation, stones from a dry one; and they do get nourished, as we said, and on clear reasoning, since they grow; what grows is not like tufa,[126] it is necessary to nourish it, as Galen says.[127] And just as they are generated from different exhalation, so they take on different colour and substance: dusky stones from burnt earthy humour, shiny-white ones from pure airy or watery humour, green ones from plentiful humour, red ones from strong heat and from matter of minimal moistness, blue ones from red substance when the red substance of something unusual is smelted out,[128] various ones from various sources. What also shows that they are nourished is that they preserve the nature of their primary colour all round, as plants do too; if there were continual accession,[129] their

[120] A sentence appears here in 1550 and 1554, though not in 1560, affirming that warmed diamond attracts straws like electrum, but diamond is so small that this is not obvious.

[121] "carnes."

[122] Presumably defying impact and blocking magnetism.

[123] "absona."

[124] See n. to Book IV at 318 (1560).

[125] The text of material about colour appearing here in 1550 but not in later editions is available as Appendix 1 in Nenci, 697–98.

[126] "tophus," the volcanic rock tufa.

[127] Aristotle's account (*Meteorologica*, 3. 6, 378a22–33; Loeb 287) is quoted in n. on 213 (1560) in Book II. Galen's statement is in his *Definitiones medicae*, 102; K. 19: 373: "Auctio est corporum in longitudinem, latitudinem et profunditatem promotio ac processus." Similar statements are in *On the natural faculties* (1. 5; K. 2: 11: "Auctio vero solidarum animalis partium, quarum esse formationem iam diximus, augmentum diductioque in longum, latum et profundum est. Nutritio autem iisdem partibus appositio quaedam est, sed sine distentione") and in *In Hippocratis librum de alimento commentarius* (2. 1; K. 15: 230).

[128] "caerulei è rubra substantia cùm alterius quàm par est excoquitur."

[129] Rather than growth.

substance would always be changing, which it is not, unless either because of veins, as happens in trees too, or because of the nature of the stone, as in agate.

But this changeability[130] is &452 in evidence in plants too, as in the [464] olive, since beyond doubt an olive is nourished and does not increase by accession. And so this exhalation is not a matter of chance; a stone, like a tree, attracts to itself especially what is ideal for it.[131] The watery parts will be pellucid when they have been again cleared of earth, and those that remain are slender and very completely mingled with aqueous humour. This is why it comes about that no very brilliant stone is heavy, and none of them lacks some remarkable power.[132] So some gemstones support[133] length of life, others safety, some wisdom, some wealth, others love, others divination, others robustness, others good luck—and others are unlucky; some make people lazy, some make them timid, some make them happy, some make them sad.

But you will say, "If brilliant stones consist of thin moist humour, and little earthy humour, how can they nevertheless be heavier than glass?" This is a sign applied to them, distinguishing the false from the genuine. But the reason is, that glass would be heavier in substance, for it is even thicker than diamond, but the substance of diamond, being very solid, while that of glass is rarefied and full of pores, brings it about that diamond is heavier than glass. However, no noble gemstone can be heavier, so that heaviness always contributes usefulness.

Someone will perhaps question why quite a number of very large gemstones are found that are of dilute and faulty colour, and spotty too, while there are numerous little ones that are choice and faultless, but big ones like that are rare. The possible reason is that in every kind there is always a &453 larger supply of inferior matter than of perfect matter. A second reason is that there are more numerous immature gemstones than stones that have attained complete maturity. A third reason, with a very large contribution to make, is that a small thing can be better perfected by nature and brought to a conclusion; this is why big gemstones can almost never be brought to final maturity. An additional point is that the kings in whose domains[134] the gemstones themselves are generated keep to themselves any they notice of outstanding size and beauty. They let only the little ones, or those of dilute colour or with faults, be exported to us.

130 "varietas."

131 "quod sibi maximè convenit."

132 "virtus."

133 "favent."

134 "apud quos."

Lodovico de Varthema[135] relates that the king of Pege[136] (a state in India) possesses Pyropos of such size and splendour that anyone who has set eyes on the king himself in darkness sees him shining with clear illumination, just as if he were illuminated by the Sun's rays. People have got used to calling the nobler kind of carbuncle "Pyropus"; there are three kinds of it— the best shines in the dark, which Albertus[137] bears witness that he has seen, so they call it "Pyropus."[138] Next to it comes one that, while being placed in a grand shiny-black vessel, shines in the dark when water is poured over it. The third kind is less valuable, and its light is only visible with illumination from elsewhere, such as daylight or candle-light. It is a property of carbuncle to stimulate the mind and make it lively; its colours benefit the spirits. However, its usefulness is not in evidence,[139] when the stone has been faulty or tiny, or its wearer whimsical,[140] as a boy is, or impeded by excessively great and serious anxieties, as princes and wise men are.

&454 Carchedonii[141] are carbuncles too, such as Germany produces, beautiful but soft, and consequently almost useless. They are ranked along with the "fluors"[142] because of their tenderness.[143] Theophrastus[144] thinks they come into being ἐκ συῤῥοῆς, that is, by a combining flow—some are of a watery colour, some the colour of an amethyst, some the colour of a hyacinth stone, some reddish, some are called carbuncles. It is a feature of all carbuncles that when chased[145]

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[135] Ludovicus Vartomanus Romanus (1465–1470), an Italian traveller in the Middle East and Asia whose account of his travels became celebrated. Scaliger (*Exercitatio* 131 [448]) regarded him as a "vir divinus." For full reference see Nenci, 609 n. 38 and the quotation there, which certainly refers to "pyropos" as jewels the king of Pege has, and that he shone in the dark, as Cardano reports here.

[136] Pegu in Burma, about 40 km NE of Rangoon.

[137] Albertus Magnus.

[138] Greek πυρωπός, "fiery red, shiny," for instance in Aeschylus, *Prometheus Bound*, 667.

[139] "latet."

[140] "inconstans."

[141] I.e. the "Carthaginian" stones. Pliny (*Nat. Hist.* 37. 104) says they were once exported to Carthage from mountains in which they were deposited by a "divine shower," and his Loeb translator (10: 249) calls them garnets.

[142] "fluores."

[143] Tender consistency; i.e. they melt easily.

[144] For reference to Agricola who attributes this to Theophrastus, see Nenci, 610 n. 40.

[145] "caelati"—a jewellers' process.

they carry off the wax[146] with them, which makes it wrong to engrave[147] them, especially because they lose that lively glint.

Opal is more beautiful than carbuncle. In the case of such a magnificent thing, to prevent your being unaware of its estimated value if you happen to find one, I shall add Pliny's words:[148] "Opal possesses the finer[149] fire of a carbuncle, the gleaming purple of an amethyst, the green sea[150] of an emerald, and all shining together in an unbelievable medley."[151] Some people have compared the colours of its pigments to the supreme evidence of lightning, to others the resemblance is to the burning flame of sulphur, or even that of a fire fed with oil.[152] Its size is a hazelnut's; Pliny recounts that the senator Nonius was proscribed by Antony on account of this stone.[153] Nothing, then, among the gemstones can be more beautiful. It is found in the island Ceylon[154] of the East Indies, with art lending a hand to nature, rather than its coming into existence like that on its own; such a variety of colour is produced by fire treatment, so it is said.[155]

But it seems to me to be a specific sort of stone, if it is the one that I now possess. Seven points identify it: the first is, as I said, that it glints with different mixed colours, such as green and gold, and red especially, which is not found in any other gemstone. But it also glints a great deal and glows. In the middle of its rounded surface[156] we can see a line &455 more glistening white than snow, but a small change in the viewpoint makes it hide, like many other things, and it is not to be seen anywhere. It is also a very heavy gemstone; though ours is shorter than a bean, and in no way larger, it still weighs two denarii—nearly fifty grains of corn.[157] This makes it a kind all on its own. It is not embellished by some

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[146] This wax was probably a coating on the jeweller's worktable, and some of it tended to attach to the gemstone, spoiling its appearance.

[147] "scalpere."

[148] Pliny, *Nat. Hist.* 37. 80.

[149] "tenuior"; the Loeb translator renders this word as "more subtle."

[150] "virens mare."

[151] "incredibilis mistura."

[152] The syntax of this sentence is unclear and the translation speculative.

[153] Pliny, *Nat. Hist.* 37. 81. Mark Antony (Marcus Antonius, ca. 83–32 B.C.) was in 43 B.C. made one of the three triumviri who were in control of the Roman republic, and subsequently was Cleopatra's lover. Antony proscribed Nonius, who fled, of all his wealth carrying out only the ring with this stone, valued at "two millions of sesterces."

[154] "Zeila." There is possible confusion with the port of the same name in Somalia, a little south of Djibouti, but here the place is clearly called an island in the East Indies. This sentence first appears in 1554.

[155] The following three paragraphs first appear in 1560.

[156] "convexitas."

[157] Evidence mentioned in Book II at 130 (1560) derived from information about the *French* grain indicates that it weighed about .056 grammes, and fits quite well evidence in Book VI at 411 (1560) derived from information about the scruple as equivalent

marking fire,[158] and it would be remarkable that it is so translucent, both for that reason and because of the variety of colouring. In fact well-coloured gemstones are rarely so translucent, like the emerald, hyacinth, carbuncle, sapphire; but it resembles this one in its exceptional hardness.

Hence it must consist of watery substance, mixed only with a rarefied and quite compact shadow (so to speak) of earth. This makes it heavy, and gives it some sort of divine influence on its wearer. I bought mine for 15 golden crowns, and it gives me as much pleasure as a diamond costing 500 gold pieces—without being valued at so much? I agree; but the jewellers know nothing of it, and openly regard it as merely a fake opal.[159] But if this gemstone is soft and not comparable to the other one in any part, could it be really an opal? I would think so, even if it does not glow with the purple of an amethyst either.

Indeed, in no other gemstone are so many varieties of colours found mingled and so bright—one must believe that there are a number of sorts, and that the ones in which those colours glow instead of white are superior; but I would think this one got from the Germans is an ounce.[160] What the [465]opal of antiquity is is not known; and the one I now have, if it is not a genuine opal, we can only guess what it was for our ancestors. When set in gold it loses much lustre, and for that reason needs to be held in four golden hooks.

&456 The pseudo-opal is far inferior; it is shiny-white and glitters, but is not translucent; it is called cat's eye.[161] In the one I have this is marvellously visible: from one side it looks all shiny-white and milky, from the other it is all quite dusky, so dusky that it looks quite dark, and this is not the outcome of changing light, since whether you turn it towards the illumination or the darkness, it is always matt-white from the direction from which it usually looks that colour, but dark from any other. And so one and the same surface displays on its own two colours virtually entirely contrary, simply with the change of viewpoint[162] when seen from opposite directions. Some of these stones are rather soft, some hard—like the one I own. It is well to offer a reason for such a remarkable property. The reason is, that the stone is crinkly,[163] and penetrable in parts, but hardly

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to 24 grains. If this is accepted, these "fifty grains of corn" are equivalent to 2.8 grammes, and the gemstone weighed about 14 carats in modern terms.

158 "non notarum aliqua igne elaborata"—sense not entirely clear.

159 "pseudopalum."

160 In weight?—but this is difficult to interpret; the stone mentioned just above was the size of a hazelnut and apparently weighed about 2.8 grammes, around a tenth of an ounce.

161 A range of jewels have been given this name, drawn from the fact that the colour seen on looking into a cat's eye, with its greenish reflective layer ("tapetum") covering half the back of the retina, depends on the angle from which one is looking.

162 "aspectus."

163 "crispus."

at all in others; it receives illumination in the impenetrable parts, but bounces it back,[164] with the result that it gives out light as shiny-white and like bright snow. Turned the other way round, it accepts the illumination, but does not bounce it back, and therefore the stone looks dark and dusky. This indicates that its substance is barely uniform.[165] But you will say, "Why does it not accept the illumination, if the gemstone is penetrable?" It is better to say that a gemstone is wholly translucent on its surface, but at one part is rough, and thus shiny-black; at the other it is polished, and for that reason is shiny and matt-white.[166]

Sapphire[167] is closest to diamond, and fifth in the ranking of noble gemstones, being of the utmost hardness, of a blue colour, and &457 quite pleasant to the eyes, if it is not dilute or faulty. Hence nothing so refreshes as the sight of emerald and sapphire—it even refreshes the human being, and as a drink helps black bile and melancholics and the stings of scorpions.[168] Albertus Magnus relates that he twice experienced the fact that sapphire cures anthrax[169] by contact alone;[170] it needs to be an excellent and big one, and to stick to the flesh for some time. The outcome is that it has an antidote's power;[171] the strike of a dipsas[172] introduces thirst, and one's hand is numbed by contact with an electric ray;[173] in the same way, the poison of anthrax is suppressed by prolonged contact with a sapphire.

The heliotrope gemstone is green, not unlike jasper; but blood-red patches or drops are adherent to a jasper, while a heliotrope is marked[174] with blood-red

[164] "sed reddit."

[165] "aequalis."

[166] "Albus"—but presumably "candidus," shiny-white, should appear here, since Book II, 314 (1560), indicates clearly that Cardano recognises the distinction.

[167] On sapphire, see n. on "select sapphire" in Book IV at 316 (1560).

[168] That sapphire is an antidote to scorpion bite is recorded in Dioscorides, *De materia medica*, 5. 139 (ed. Wellmann, 3: 99).

[169] "anthraces."

[170] Nenci (614 n. 46) has identified the quotation, in *De mineralibus*, lib. 2 *De lapidibus pretiosis*, tract. 2 *De lapidibus nominatis et eorum virtutibus*, cap. 17 *De incipientibus a 17 litera quae est S.*

[171] "alexipharmacum," a word previously used in Book II, 195 (1560).

[172] A kind of snake whose bite provokes thirst in the victim (*OLD*).

[173] The fish. Reading "torpedinis" with 1560; the earlier 1550 and 1554 editions read "remorae." To mention the "remora" was Cardano's initial mistake, rectified in the 1560 edition; it means originally "delay" and was later applied (as now) to a species of fish with a sucker by which it was supposed to attach itself to ships and delay or stop their passage. In fact it attaches itself to other fish and sucks their juices, and does not administer numbing electric shocks as an electric ray does. See on these fishes Brian P. Copenhaver, "A Tale of Two Fishes: Magical Objects in Natural History from Antiquity through the Scientific Revolution," *Journal of the History of Ideas* 52 (1991): 373–98.

[174] "interstinguitur."

bands. When exposed to the Sun under water, its lively redness and greenness make it scatter a saffron-yellow colour, so that it appears to cloud the atmosphere over and display an eclipse of the Sun.[175] There has been no opportunity of seeing this up to now, any more than a genuine Astrite.[176] This gemstone is hard, one that shows the Sun glowing inside as it rotates. Jewellers imitate it with chalcedonian onyx,[177] which loses its sheen and powers for a little, if it is much impaired by heat or sweat. A better gemstone is the one made from a rather brilliant sard,[178] which is called carnelian;[179] the best one is made from this as well as from other quite hard hollow stones, because the cavity picks up the illumination; however, only a true Astrites retains its beauty and splendour.

On the basis of the starry meaning of the word it differs little in powers and substance, &458 but does differ greatly from the Astrites, since it is not a gemstone nor is it translucent.[180] It is all marked with patches of an ashy colour, which are the origin of its name.[181] It moves about of itself in vinegar and even in wine, and imitates the movement of animals—moving forward to the side, then moving back. In the past, Rabbi Ben Ezra[182] was aware of this stone and its powers; it is common with us, and cheap. After pondering its movement quite often, I concluded that the stone consisted of rarefied moistness, and could be

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[175] He is clearly aiming to justify heliotrope's derivation from Greek: "sun-turning." But this indicates its rotation with the sun's journey across the sky.

[176] *OLD* under "asteria" offers "a precious stone, perhaps either the asteriated sapphire or cymophane"—Pliny (*Nat. Hist.* 37. 131) writes that the *asteria* "holds its high position owing to a natural peculiarity, in that a light is enclosed in it, stored in something resembling the pupil of the eye. This light is transmitted and, as the stone is tilted, is displayed successively in different places, as if capable of locomotion within. When it is held up to the sun, the same stone reflects bright beams radiating as if from a star—and thus it has acquired its name."

[177] See n. 8 above.

[178] "sarda"; Caley and Richards (*Theophrastus on Stones*, 122–23) cite Pliny (*Nat. Hist.* 37. 105–6) and Theophrastus to show that this signifies varieties of chalcedony suitable especially for seals. They are quartz-coloured, with a little ferric oxide. One variety of sard is now called carnelian, a bright red chalcedony of clear rich tint..

[179] "carneolus"; see Agricola, *De natura fossilium*, Bk. 6, trans. Bandy, 114, 132. The word indicates its fleshy colour.

[180] This sentence is hard to interpret; it replaces one in earlier editions which distinguished the "Astroites" from the "Astrites," and both these very similar names are "starry" in origin from words for a star. The "Astroites" is mentioned again at 507 (1560), for its property of moving about in vinegar. The distinction between the two seems unclear, although the "Astroites" is evidently the subject of the present sentence.

[181] They resemble stars in appearance. See Agricola, *De natura fossilium*, trans. Bandy, 1: 15. The same translation (226) relates the appearance to the stone's origin from fossil coral and crinoid stems.

[182] On this man see n. 103 above. Nenci (604 n. 30 and 616 n. 50) evidently found the reference here hard to trace.

converted into vapour by the power of vinegar and wine, so that in its unsuccessful search for escape the vapour easily propels the stone (which is anyway light) one way and another; it does not emit bubbles, which indicates the rarefaction of the vapour. Hence it should not be regarded as possessing large passages. There are people who wear them attached to their necks and suppose this brings them victory. I have set about writing here only what I have experienced; but I was keen to include this, so that anyone can try it;[183] as I said, I have quite often made the test in wine and vinegar.

Jasper is similar to heliotrope; provided it is green, and is suspended directly at the stomach, Galen wrote that it significantly strengthens it.[184] When used thus, too, we have seen it stop blood from dripping everywhere, but especially from the nostrils—which is not surprising, since it possesses vast astringent power. As chosen from the East, it is not very small, shining, green, scattered with numerous little blood-coloured drops closely imitating living blood.

&459 The agate stands on its own in opposition to all other gemstones, and is itself counted with them, but is of such variable kind that you would not think it a single stone—shiny-white, reddish, saffron-yellow, ashy, green, shiny-black, motley,[185] blue. To get on with it:[186] the colours of all the other gemstones are not enough for this single one. With playful nature it represents groves, meadows, animals, rivers, flowers, trees. The agate of King Pyrrhus[187] is very famous in history, depicting the nine Muses with Apollo strumming the lyre in their midst, each of them with their own décor,[188] so that it looks as though nature is contending with the painter—and here it should be called a miracle rather than a gemstone. We possess three agates: in one nature has painted the hemisphere of the sky, with spheres picked out; in the middle is the round earth, as though floating on the waters. The second appears to emit smoke from a gap, which clouds the air. And what commands admiration here is that there is one colour

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183 "quisque possit experiri." Just before, the "pinguit" of 1560 is clearly a typographic error for "piguit."

184 Nenci supplies the reference here: "Proprietatem nonnulli lapidibus quibusdam testimonio suo adscribunt, qualem revera habet iaspis virens, nempe stomachum adhaesu ventrisque os adiuvans" (Galen, *De simplicium medicamentorum facultatibus*, 9. 19; K. 12: 207). But despite what Cardano says, Galen did not agree about its reputation thus stated; he tried out himself for some time a necklace of jaspers hung from his neck so as to lie at the level of the stomach's orifice, and they seemed to do him no good: "apparebant nihil secius prodesse."

185 "varius."

186 "Quid moror?"

187 Pyrrhus (319–272 B.C.) created a large kingdom for himself in Epirus (in Greece) and defeated the Romans memorably in 280–279 B.C., but was ultimately killed in a street fight in Argos (*OCD*). For his agate see Pliny (*Nat. Hist.* 37. 6) whose account is that of Cardano here, except for "nature contending with the painter."

188 "cum propriis ornamentis."

for the smoke, another for the air, which is dimmed by it—the smoke is as though shiny-white and thick, the air reddish and middling translucent.[189] The third, much more remarkable than the others, has a virtual likeness of Galba depicted thus: not on the surface, but as if under glass; yet it is a genuine gemstone, not glass, because where it touches a [466]finger it all shows red; it presents the appearance of jasper.

I have verified that it brings on sleep, and it displays all dreams full of &460 seriousness,[190] with no nonsense, and it increases prudence. Still, as while carrying it I suffered many misfortunes, outside the boundaries of error and expectation, I have now put it away for a second time. Other agates represent birds' eyes, and we have one like that; others, fishes' eyes. The Pontic one,[191] which is marked with blood-coloured or matt-black drops, represents the likenesses of mountains and deep valleys. Some represent human eyes, and are Leucophthalmi;[192] some those of a wolf, Lycophthalmi,[193] some those of a she-goat, called Aegophthalmi.[194] I have seen a translucent green one beautifully marked with two shiny-white lines, a gemstone which I thought of uncertain nature, rather between agate and prassium.[195] For as in the case of animals, mules are the offspring of an ass and a mare, and a lycisca[196] is the offspring of a wolf and a dog, similarly stones are sometimes of mixed and diverse kind, with mingling of their matter and of the causes giving rise to them.

But about King Pyrrhus's agate: I regard it as too ridiculous for it to have been so precisely decorated and marked by chance. Accordingly, this came about thus: a painter used strong colours to paint some stone of the marble type,[197] so that the nine Muses were admiring Apollo strumming in their midst. Thereafter, by chance or deliberately, that stone lay buried for many years, in the spot where agates are usually generated; and so it comes about that a translucent watery agate was generated all round, and then, when found, it was representing the Muses and the famous Apollo, as if fashioned by nature's diligence when the

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189 The following three sentences first appear in 1560.

190 "gravitas."

191 "Ponticus"; it appears from a passage in Agricola cited by Nenci (618 n. 55; *De natura fossilium* 7, trans. Bandy, 142) that a river Pontus in Thrace is the source of the name here.

192 Greek for "white eyes."

193 Greek for "wolf eyes."

194 Greek for "goat-eyes."

195 See n. to Book IV at 318 (1560).

196 Lycisca is mentioned by Ovid (*Metamorphoses*, 3. 220); there the Haupt ed. prints "Lycisce," not Lycisca. The word means "female wolf," and is a proper name there, of one of the hounds of Actaeon, the man who saw Diana naked; his hounds then turned upon Actaeon.

197 "genere."

agate was already a gemstone. For if wheat ears and moss sticking to trees pass over into an agate with the passage of &461 time, as in an agate I have had with five wheat ears, which you might say had just fallen off the stem,[198] yet they were stone—and gemstone too. In the same way too, a significant part of a fly was there. How much more easily could that soft painted stone pass over into an agate?

And so, if anyone cares to take notice of the locations of agates, especially where translucent ones are generated (this is essential), and buries a picture in permanent colours, like blue and gold, consisting of metal—then, especially if he smears the work with Punic wax[199] tempered with a little oil, or with some other permanent yet translucent ointment, such as among us is called liquid varnish, which is generally applied to the more costly pictures when they are finished, an agate will be born painted in this way.

But you will say: "An agate painted like this would be common if it could be arranged with so little technique." But you are overlooking firstly that the burying should be done where agates are generated, and further that an agate which is contrived to be brilliant and translucent, and then within a few years to pass over into a gemstone before the picture fades, and not to be diluted too soon by any external humour lest the image be lost, finally happens to be dug up perfect. How many fish are there that no one ever catches, how many beasts[200] in the woods and birds that no one ever caught, and they die by themselves[201] in their own places? Reckon that that is the number of gemstones lurking in the places where they were generated, never emerging into the light, but as they were formed through age into their first mother, the Earth, they return in the same way. Although &462 agate is distinguished for its diversity, yet because it does not shine much, it rarely commands a vast price among gemstones.[202]

Chrysolith is regarded as much nobler than agate; our people call it topaz, just as they call genuine topaz chrysolith; Pliny[203] says that chrysolith is a gemstone of golden colour, and glittering; and these statements are true of our common topaz, though actually the German topaz is softer, as are most other gemstones that are found in the frigid zone, because heat cannot thin out their juice so much, and harden the gemstone (because, as I said, the reason for hardness is perfect solidification, which occurs when the tiniest parts are mixed in together);

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198 "triticum," adapting its meaning slightly.

199 *Pontic* wax ("cera Pontica") is mentioned by Castelli, who refers to Galen's *De compositione medicamentorum per genera.* In that work (7. 4; K. 13: 83) can be found a set of recipes for the "Ponticum medicamentum," and one of these may be relevant here.

200 Reading "ferae" for the "ferè" of 1560.

201 "sponte sua."

202 Nenci (621 n. 59) notes that Pliny (*Nat. Hist.* 37. 139) said the same thing: "Achates in magna fuit auctoritate, nunc in nulla est." On agate, see n. 99 above.

203 *Nat. Hist.* 37. 126.

however, Pliny is not talking about that chrysolith, but about the Oriental one, which is well known to be very hard, and of such hardness that it yields very little to sapphire, or not at all. And so this caused me to order my portrait to be chased[204] on a chrysolith, with the first letters of my name and forename.[205] I chose this stone for its extreme hardness and hence the work's permanence, and it has a good deal of brilliance. A chrysolith without some black patches to spoil it is uncommon; otherwise it is no ordinary gemstone. It is thought to restrain libido beyond all belief,[206] if worn in contact with the flesh. Albertus writes that if it is placed in boiling water, it removes its ferocity; this is not the case, but as usual he makes up a lot about these points;[207] we have recounted &463 in their place some details of his alleged experience in connection with gems and stones, and will recount more; he was not actually a liar, but too credulous, as is the way of people who concern themselves with such things and write them down.

But I reckon that the gem is of enormous coldness, on this evidence, that when placed under the tongue it mitigates the thirst of fever sufferers—although the feature is common to crystal and to a number of other gems, but not so obviously. So now we have topaz, which was the chrysolith of antiquity, and contrariwise, what we now call chrysolith is the true topaz of the ancients. Pliny in fact says that topaz is a dull-green gem, which is unique among gems in being soft enough to be polished by a whetstone, and it is cut by a file—all of which is very true of what our people call a chrysolith; it really is cut by a file,[208] and is of a golden colour, not a pure one, but dull-green, and because of its softness people polish it with wheels made of tin.[209] Also, it loses its glitter [467]of itself, so much so that pretty though it is, no one thinks it worth wearing. They call it piradotum,[210] and a cliché has grown up among jewellers, that having one piradot is too many, presumably because its softness makes it of little value. However, I have found that fifteen grains of it when drunk are of immediate help to melancholics.

But before leaving the account of topaz and chrysolith, this ought to be noticed too, that there are some gems that grab[211] wax, and some that do not

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[204] The jewellers' process.

[205] The text of material on the differing problems of sculpture and engraving which appeared here in 1550 only is available in Nenci, Appendix 2, 698.

[206] "opinio."

[207] Nenci (622 n. 62) has identified the passage, in which Albertus says that a topaz placed in boiling water cools it so much that the topaz can be taken out at once by hand, and one of his associates did this at Paris.

[208] Pliny, *Nat. Hist.* 37. 109.

[209] "stannea."

[210] In Plin. *Nat. Hist.* at 37. 107 the translator renders the word "topazus" as "peridot," a present-day word.

[211] "rapiant"—its meaning becomes clear just below, in discussing seals.

do this at all, among which sard is the most notable; &464 even chrysolith is not entirely immune from this disaster. So, to return to my topic: the sard stone is of red colour, of which the species which is more dilute and less red is called carneolus,[212] and then with a letter changed, corneolus. Since it has onyx[213] at the bottom, it is called sardonyx, and I have one like this, at the bottom of which onyx is visible, at the top sard. Sard,[214] as we said, is mostly developed from onyx. Sard, corneolus, and sardonyx are very suitable for seals,[215] for three reasons: firstly, because it does not grab wax; secondly, that it is easy to chase, being tenacious and of middling hardness; thirdly, because it is not easily blunted[216] by a humour.

The gem onyx is soft, so called from its resemblance to a fingernail.[217] There are a number of kinds. Chalcedony, so named from the town in Bithynia, into which it used to be conveyed; it is properly compared in colour and translucency to a fingernail. Albertus relates that he found that if this stone is hung from one's neck, it reinforces all the body's powers, which is not incredible; by its coldness it constricts and unifies the spirits, by its light it strengthens them also by the temper of its heat. On the same basis it is thought to restrain amorousness[218] when hung from the neck, and hence the Indians have regularly carried it everywhere for this purpose. But it is more noble, because it is oriental. Among this kind is the blue one, because it is very costly, and I have only seen it once. There is another kind of blue one, pale at the top and opaque, but shiny-black at the bottom, which is called Nicolus; it makes the person wearing it gloomy and reckless, and disturbs him with terrifying dreams; it concentrates[219] the spirits so much that it arouses &465 gloom and perplexity. A third kind is of rusty colour at the top, shiny-black below, shiny-white in the middle, and is called "eye" by most people. If two fragments of onyx are rubbed together, they acquire so much heat that it can hardly be endured. Large fragments of it are found, so large that it seems more like a kind of marble than a gem; there are at Rome six small columns of this stone in the temple of St Peter.[220] At Colonia Agrippina[221] there is

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212 Castelli notes that sarda = lapis sardus is sometimes also called Carneolus. Agricola (*De natura fossilium*, 6, trans. Bandy, 132) wrote of sard that "the gem merchants call it *carneolus*, because it has a color similar to flesh."

213 See n. 8 above.

214 See n. 23 above.

215 "sigillis" (i.e. seals for sealing documents, not the animals).

216 "humore non facilè hebetetur"; 1560 reads "humores."

217 The Greek word "onyx" means a finger (or toe) nail.

218 "Venerem." This and the next sentence appear first in 1554.

219 "cogit."

220 The texts run "B. Petri," presumably "Beati Petri"; the Saint is meant, just as at 480 (1560) there is reference to the churches of "B. Marci" at Venice and of "B. Ioannis Baptistae" at Florence, as is Neo-Latin usage.

221 Cologne in Germany (*Orbis Latinus*).

still an onyx wider than one's palm, mentioned by Albertus in the past and now by Agricola[222] as being embellished with shiny-white veins so as to represent the heads of two young men, and with shiny-black ones which depict a snake making its way down from the top of one young man's head down onto the lower part of the other's. Also, on the jaw of one of the men there appears a likeness of the head of an Ethiopian with a black beard; the rest of the stone reproduces the colour of a fingernail, as these stones usually do.

But someone may reasonably wonder what the source is of these figures on gems and stones. It is beyond belief that every figure arrives by chance, since (as we will say below) many stones of the same kind keep the same figures. And so in my view it must be said that there are two kinds of figures and likenesses: the one that always appears on the same stones, and this one emanates from nature, which operates just as in the case of plants it preserves the number and plan[223] of the leaves and fruits — this kind of figure has power and means something.[224] Such a kind of figure was found in a black stone, cone-shaped, with its summit cut off; it had a snake very &466 beautifully represented on its top, as though it were painted, with the lower part paler, and not translucent anywhere. The man who gave it to Albertus[225] used to state that upon it more than five hundred snakes had had coitus; it had been found in a meadow among the Swabian mountains, and when the snakes under which it lay hidden had been killed, it was carried off by the soldiers of the prince with the head of a huge snake which was touching the stone, and taken home. So it must be concluded that nature endowed this stone with the power to attract snakes to itself.[226] But this would appear extraordinary, unless it were established on Pliny's testimony that serpents' eggs are found round which the serpents copulate — hence this is painted on heralds' staffs. In fact Pliny says, "We have seen an egg the shape of a small rounded apple, with a crust of cartilage, like the badge of a Druid with the close-packed suckers of a polyp's arms. They say these are collected in Gaul at salt pans and in the foam of intertwined serpents." And it seems to be making more for concord on the basis of generation than for lawsuits, though they do contribute to the popularity of princes and to success in lawsuits.[227] It is actually accepted that

[222] In *De natura fossilium*, trans. Bandy, 6, 134.

[223] "rationem."

[224] Conrad Gesner (*De rerum fossilium*, 4–5) quotes this passage, noting that Cardano probably acquired it from Agricola.

[225] Albertus Magnus, in a passage identified by Nenci (at 628, n. 74).

[226] The following six sentences first appear in 1560.

[227] In fact at this point Pliny (*Nat. Hist.* 29. 52–54) wrote that "The Druids praise it highly as the giver of victory in the law-courts and of easy access to potentates. Herein they are guilty of such lying fraud that a Roman knight of the Vocontii [a Celtic tribe of southeastern Gaul], for keeping one in his bosom during a lawsuit, was executed by the late Emperor Claudius, and for no other reason."

a Roman knight of the Vocontii was summoned and killed by the Emperor Claudius, because he was found carrying a serpents' egg in his bosom. I know Pliny does not lie, but I do not know whether a man unschooled in philosophy would tell the truth.[228] It is also credible that stones were found in a field at Verona, in which, as Leo Baptista Alberti[229] recounts, the image of Solomon's seal[230] was being found, depicted to perfection—and the stones being thus decorated by nature acting deliberately,[231] and &467 not by chance, it is credible that some special power resides in them.[232] There are two kinds of these.[233] First, that it is by chance, so to speak, and yet necessary, like the roundness of things that come into being in the sea; they get rounded through long attrition by waves which eats away any prominence.[234] But these are not precisely rounded, nor in all cases; when they are taken out before reaching perfection, they are hardly rounded at all, nature not offering anything of the sort.[235] Those extracted in Poland are in the shape of jars for possibly the same reason, because they develop positioned round another stone; or because, as in a certain kind of Aetitis,[236] the included earth does not coalesce; external heat can shape the vessels. It is not constrained by heat, since only moistness is poured around it. Or the reason is that nature has chosen this form especially, and makes this one its [468]aim, as in the case of

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228 The passage on which Cardano is drawing is, as Nenci has traced it, Pliny (*Nat. Hist.* 29. 52–54). There is still uncertainty about the Latin text. See n. 227.

229 Born at Venice ca. 1404, d. 1472 or 1484. A distinguished architect, musician, poet, painter, and philosopher at Florence and Rome, and celebrated above all for his treatise *De re aedificatoria*. See A. Grafton, *Leon Battista Alberti* (New York: Hill and Wang, 2000).

230 "Solomon's seal" is a traditional name for flowers of the *Polygonatum* genus, perhaps because they have small dangling flowers which might form two superposed or interlaced triangles, thus creating a six-pointed star, a traditional symbol of the race of Israel, of which Solomon was king after David his father.

231 "ex proposito."

232 The following eight sentences first appear in 1554.

233 Two kinds of what?—"harum"—feminine gender. Images? The sense suggests *causes*—and see just below, "causam eandem habere possunt." But the text then continues with "Prim*um*. . ."—masculine or neuter

234 See Pseudo-Aristotle, *Mechanica*, 15. 852b29–853a4, where the author argues that what is further from the centre moves faster and is therefore struck harder and gets more worn—hence the rounded pebbles and shells. In Pseudo-Aristotle, *Problemata* (23. 36, 935a37-b2; Loeb 37), the thought is similar: ". . . the sea, moving in every direction, breaks off the points equally."

235 "nihil tale proponente natura"; meaning unclear.

236 On aetites, Adams, commenting on Paulus Aegineta (who does not apparently himself use this word), writes (3: 227): "The Aetites, or Eagle-stone, is a species of oxide of iron." On this stone, Pliny (*Nat. Hist.* 37. 187) says that it is so named because of its colour resembling that of the white-tailed eagle. Agricola (*De natura fossilium*, 5, trans. Bandy, 102–3) discusses the geode (or gaeode) and aetites.

the round stones of the island of Cuba.[237] Again, of those that nature proposes, some resemble figures of substance and form, others pictures, as it were. Any that occupy the place of a form are also generated by chance, but not in all cases.[238] Those then that are not found always in the same stones, but uncommonly, are generated by chance just as in the clouds, and are of no virtue, like those in the Alabandic[239] monkey-stone found at Freiburg,[240] and the one of the same kind that had a little red shield with four lines running round it—the first and third matt-white, the second and fourth red. And at Annaeberg another Alabandic stone had the form of a cross, but this was more a form than an image.[241] And amid the bituminous stones of the Hercynian &468 forest, pyrites is found which reproduces various forms by marking them with golden patches—forms such as an ostrich,[242] salamander, cock, a bearded priest, then the Blessed Virgin Mary carrying her son in her arms.[243] Similarly, in an Alsatian lake near the Meissen[244] mountains, figures of frogs and fish are found depicted in copper on the surface of stones—so often, so painstakingly, that you would say it could hardly occur by chance. Münster[245] mentions having at his place a likeness of an olruppa; unless I am wrong, we call this "botta." Certainly this fish has a very large liver, and

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[237] Oviedo (*West Indies*, 20) says that these very round stones are "large enough for any artillery, and if they should be desired of one-hundredweight, two-hundredweight, or larger, they could be found.."

[238] "Quaecunque verò formae loco sunt, casu etiam fiunt, sed non in omnibus."

[239] Alabanda was a town in Caria in Asia Minor, and Pliny (*Nat. Hist.* 37. 92) refers to a kind of carbuncle originating there, but does not mention the monkey tale.

[240] "in alabandico lapide simiae"—but Agricola (*De natura fossilium*, 5, cited by Nenci, 631 n. 81; trans. Bandy, 110), writes of stone from Freiburg "qui lineamenta simiae effingit," but does not call it Alabandic at all; he says it belongs with stones of a third kind he mentions, suitable for making glass. So do the materials with a red shield marking and a cross marking, which come next here and in Agricola.

[241] This final remark is not in Agricola, and it is not obvious how one would tell.

[242] "passer marinus"—"sea sparrow"—an extraordinary name apparently given because the birds were imported to Rome by sea (*L&S*).

[243] The remainder of this paragraph with the following two paragraphs first appear in 1554.

[244] Misnensian, i.e. of Meissen, near Dresden in Saxony (*Orbis Latinus*). It is a very long way from Alsace, and I cannot explain this.

[245] Sebastian Münster (1489–1552) was a theologian in Germany and Switzerland who published a Hebrew Psalter and a Hebrew Bible, and later devoted himself to geography and wrote a *Cosmographia* or description of the then known world (1544) which was often reprinted. There is an estimate of his achievement with details in C. J. Glacken, *Traces on the Rhodian Shore* (Berkeley: University of California Press, 1967), 363–64. In Lib. III of his *Cosmographia* (1550 ed., 432) he mentions receiving the gift of a stone on which was delineated by nature the form of a fish called "Olruppa" and "Treisa" by the Germans, and with a large liver. The figure supplied has more the head of a dog than that of a fish, and appears again at 721, where Münster returns to the topic. Nenci

is like a gudgeon;[246] one might call it a river gudgeon, after calling it Olruppa, which I know is not a Latin word. So are we to suppose that at some time this fish has stuck to a stone, and so with the stone getting more porous, the copper broke through at that part? Or instead that water dosed with the fish's semen passes over into metal?—metals themselves are made from water. Or is there some star that is imprinting that form? But the star's power would be constrained in too narrow a target.[247] Or that nature shaped this by means of some resemblance, as occurs in the generation of animals? It is thus better to transfer these to fixed species of stones, as occurs in animals and plants, when their shapes have been correctly delineated, and the result is frequent.[248] But a rare chance, and figures that are not finished off, like some human face in our agate—such things then occur on an inconstant basis and by chance, as happens in clouds, and when molten lead is thrown into water, and with bones of the pike[249] being compared to the shape of country tools. So the shapes of agates are of this kind, &469 and there is no power in them (I mean in the shapes), but they are simply natural.

There is considerable uncertainty about the artificial shapes: though no line of thought[250] can convince us of this, they still do possess powers. This is proved rather by an instance[251] than by any line of thought. So the reason may be either that there is a power resident in the stone which ignorant folk credit erroneously to the shape, in the way that Galen used to explain the chased jasper[252]—or else because it is attributable to fate; for there is no one who has, for instance, a way

(632 n. 83) also notes Cardano's confusion here about where the Meissen mountains are situated—not near Alsace.

246 "gobius," a small fish.

247 "terminus."

248 "Ergo melius est haec ad ceras lapidum species transferre, velut in animalibus et plantis, cùm rectè figurae delineatae fuerint, et frequens eventus." On the development of thought about the origin of fossils, see Rudwick, *Meaning of Fossils*, esp. chap. 1, "Fossil Objects." And on the interpretation of diverse entities as "jokes of nature," see P. Findlen, "Jokes of Nature and Jokes of Knowledge," *Renaissance Quarterly* 43 (1996): 292–331.

249 A fish.

250 "ratio."

251 "exemplo."

252 This remark should be read in conjunction with 458 (1560), where Cardano writes: "Jasper is similar to heliotrope; provided it is green, and is hung directly from the stomach, Galen wrote that it significantly strengthens it." Nenci cites Galen's *De simplicium medicamentorum facultatibus*, book 9 [9. 2; K. 12. 207]; the passage runs "Ac nonnulli quoque annulis inserunt, scalpuntque in eo draconem radios habentem; velut rex Nechepsos memoriae prodit . . . Proprietatem nonnulli lapidibus quibusdam testimonio suo adscribunt, qualem revera habet iaspis (Ἴασπις in Greek) virens, nempe stomachum adhaesu ventrisque os adiuvans." Though this accounts for the benefit of hanging a jasper round the neck, it says nothing about the shape of it. On Galen's failing to benefit, see n. 184 above.

of keeing safe from his enemies.[253] But not safe through possessing a chased ring—rather, the ring seems to have this ability—because it belongs to the man who has achieved this good luck by fate—or because we are naturally like this: responsive,[254] brave, wise, not thanks to a chased stone, but through human nature—or because they expose themselves to perils through groundless hope, or are devoting themselves to business, and are helped by fortune—that is why they imagine it was the work of seals.[255] So there are many ways through which belief occurs that the power lies in the artificial shapes.

But now we need to show that neither these products of modelling or of the household,[256] nor anything else hand-made can possess any powers beyond the power of fortune. Since mathematical shapes cannot in fact do anything, and are no more the principles of things than numbers are, it is clear that of themselves and by themselves[257] they can do nothing towards performing or interchanging the actions of nature. But if you are in hopes of gaining power from heaven by means of observations[258] (most people assert this), there needs to be some principle for the form; a natural action is that of a form. What is thus needed is for the natural form to be changed, not the &470 shape. I know it is a memorable tale they tell about Hermione's ring[259]—that all who wore it perished wretchedly. More recent and more truthful is the tale about the horse of Seius,[260] whose owners (the first was Cnaeus Seius, then Dolabella,[261] afterwards Cassius[262] and

[253] "nam nullus habet quin, gratia exempli, tutus fuerit ab inimicis."

[254] "prompti."

[255] "sigillis" (i.e. seals for sealing documents, not the animals).

[256] "neque plastices, aut domus, aut aliud quicquam . . ."

[257] "spontè . . . ac per se."

[258] "observations"—I am not sure what kind—maybe "observances" is suitable here, and *OLD* supplies a wide credible range of meanings.

[259] In mythology she was the daughter of Menelaus and Helen, but no ring is associated with her, so that the likelihood is that Nenci's ingenious suggestion (634 n. 85) is right, that *Harmonia* is meant (cf. Brumble, *Myths*, 59–60) and a commentator on a passage of Statius's *Thebaid* does mention a poisoned ring which overwhelmed Harmonia and other mythical figures with distress.

[260] Nenci (634 n. 86) has traced in Aulus Gellius (*Noctes Atticae*, 3. 9. 2–7) the account of a horse which was born in Argos in Greece and first owned by one Gnaeus Seius. It was thought comparable to the mythical horses of Diomedes in Thrace, which Hercules had captured by killing Diomedes (see Brumble, *Myths*, 158). While very admirable, it notoriously doomed its owners—a succession of notable Romans—and their families to disaster.

[261] Publius Cornelius Dolabella (ca. 80–43 B.C.); on being defeated he killed himself.

[262] Gaius Cassius Longinus; one of the murderers of Julius Caesar; he killed himself when believing the day was lost at the battle of Philippi in 42 B.C. against Antony and Octavian.

Antonius) perished cruelly and miserably through execution or by chance. It was conspicuous for its form and character,[263] of an admirable colour, in fact bay.[264] A similar tale is told about the gold of Toulouse, which the Roman Cepio[265] carried off, and he himself perished painfully. These are not the deadly consequences[266] of shapes,[267] but of fate, on which we have spoken elsewhere.[268] Let it suffice for us to have touched upon chance events and those that are brought about by technical skill.[269]

We must now discuss why rock crystal has six surfaces—it hardly ever has more or fewer. The reason is that, just as bee cells[270] are surrounded by others, and consequently are themselves hexagons, pieces of crystal are surrounded by other pieces. But why are items surrounded by others of hexagonal shape, while a sphere is surrounded by twelve similar spheres, not by six?[271] It will be better to explain this power by the nature of the body; every body surrounded by rectilinear surfaces is characterised[272] by length, width, and height, but this one consists of six opposite surfaces, which is why crystal has six surfaces, and so do the rest of the gems of this kind, such as beryl.[273] Again, as I said, nature has

263 "forma . . . ac virtute."

264 "puniceo."

265 This was "Quintus Servilius Caepio (1)" who around 105 B.C. captured Toulouse and the sacred treasure there. The gold subsequently vanished, his complicity was suspected, and for that and other reasons he was exiled to Smyrna, where he died (*OCD*; he is also referred to in Pauly-Wissowa).

266 "exitia."

267 "figurarum."

268 Cardano's *De fato* was written in 1533 and "almost certainly destroyed after 1570" (Maclean, *De libris propriis*, M16 [53]).

269 I.e. presumably both about gems that get like that naturally and about those that are made so.

270 "Casulae." Neither *OLD* nor *L&S* mentions that this word can mean a hexagonal cell in a honeycomb, nor apparently does "capsula" or "cellula" either. But "cella" does, and according to *OLD* Varro (*Res rusticae* 3. 16. 5) mentions a honeycomb "cella" with "sex angulis," as here. I think Cardano probably intended to write "cellae" or perhaps "cellulae."

271 Spheres all of the same size can be packed so that each touches twelve others. Coxeter (*Introduction to Geometry*, 407–8) illuminates this by pointing out that they touch each other at the midpoints of the twelve edges of a cube. Rouse Ball (*Mathematical Recreations*, 149–51) also deals with this problem.

272 "distinguitur."

273 Emerton (*Scientific Reinterpretation of Form*, 33) aptly points out how Scaliger (*Exercitatio* 118 [433–35]) very pointedly criticises Cardano here. "Sic non omnis Crystallus sex finita superficiebus ab alia tangitur"; i.e. he notes that an actual crystal is usually free-standing, and can't be moulded by what doesn't touch it. Further, what about the ends of the crystals? They are not planes at right angles to the crystal's axis—how can sharp ends adjoin each other? The actual six-sided relationship here is a 2-dimensional

established this for the sake of generation, as we will mention in connection with plants; in the island of Cuba in the other hemisphere,[274] stones that are precisely spherical abound, thanks to nature alone. &471 However, their usefulness is quite obscure, rather than less certain.[275] But crystal consists of watery substance, and so melts very easily in a fire, and passes over from a remnant[276] into glass. Similarly, it needs to be said that it does not itself originate from ice, though it is commonly found among snow, but from a humour of its own kind; when the ice that hangs from mountains drops down on warming with fire, it melts, but crystal does not, unless it is surrounded with fires and diligently assailed with wind and flame. What protrudes from mountain tops does not happen because it was generated like that, or because it has ever been ice, but because earth and the softer stones are liquefied by winds and snow, and flow downward, and the [469]rock is laid bare. Hence crystal generated between stones and underground seems to be suspended, whatever way it sticks on. Crude silver is generated rarely on the tip of a crystal, but often in the body of it. This is because it is not classified[277] among the defects of crystal, but among its notable distinctions—such as, that it is reckoned more beautiful, and a gem of less common incidence.[278] Also found in it is a kind[279] like amethyst, so dark that some people regard it as beryl. I have also seen water generated in a crystal, and in the water a thin black body which was carried to and fro with the water's movement, because the water was lighter,[280] and so while it was coming to rest, the crystal was rising upward of itself. We used to talk of this as a joke, and some people were convinced there was a demon shut up in the crystal.

But why does it not glitter much? Because it is soft; no soft gem glitters. But why does a soft one not glitter? It is because it does not reflect &472 all the rays, or very many of them. So what glitters a lot cannot be so translucent; and so crystal is more translucent than diamond, because diamond glitters far more.

There is another reason: that where a surface is precisely smooth, rays are reflected internally at exactly the same angle, and so get stronger. If the surface is not hard, it will not be precisely plane, so that rays will impinge and be reflected at various angles, and be dispersed and hindered.

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one, not a 3-dimensional one: "Omnia enim tibi plana video."—"I see everything is 2-dimensional to you!"

274 "orbis alterius," which should properly mean "of the other sphere."

275 "At obscurior est in illis utilitas,non autem minus certa."

276 "vestigium."

277 "reponitur."

278 "rarioris exempli gemma."

279 "species." This sentence first appears in 1554.

280 "quod esset illa levius"—might mean either that the water was heavier or the body, depending whether "illa" is nominative or ablative.

Crystal being a white gem, prannium[281] is a black translucent one, a rare combination. Its root[282] appears to be of crystal's kind,[283] and is found in Saxony. It sometimes happens that other gems are being born from the black root, as in Cyprus the sard arises like this from something translucent[284] which is not exactly black, and as the hyacinth[285] does in Meissen at Volchestein. There also arise, as we have said, red ones, green ones, blue ones, and amethyst-coloured ones.

Nebrites[286] is not a gem, but an uncommon stone—opaque, recalling the colour of deerskin to perfection; our jewellers call it "Garatronium"; it is believed to protect its wearer completely, so as to be invulnerable. It is commonplace and cheap, but pretty.[287] More noble than this, but not very different, is the pazar, a name which people corrupt into bezar.[288] This is not a gem, but is of a soft and ashen colour, the size of a hazelnut, and famously resists all poisons. This is the celebrated stone that everyone praises, yet almost no one is &473 acquainted with it—the one that Scribonius Largus, though he was Caesar's[289] physician, falsely described as the teardrop of deer found in Sicily,[290] although it is accepted that it is normally found in Pely, a region of Eastern India. There they say that

[281] This is "prase," a leek-coloured variety of quartz, mis-spelled here; see n. 47 above.

[282] "radix."

[283] "genus."

[284] "translucido."

[285] In the related passage from Agricola (*De natura fossilium*, 6; trans. Bandy, 139) more complex distinctions are drawn between these and similar stones.

[286] This is originally a Greek word for a precious stone, derived from the word νεβρίς for the fawn-skin worn by Bacchus and his devotees; it is used (in Latin) by Pliny (*Nat. Hist.* 37. 175) (*OLD*), and the supposed derivation was known to Agricola (*De natura fossilium*, 6; trans. Bandy, 143). Albertus Magnus (cited in Nenci, 638 n. 91) mentions a stone called "Gagatronica," and Cardano's "Garatronium" here probably represents this.

[287] The remainder of this paragraph first appears in 1554.

[288] Nenci, 638–39 n. 92, discusses whether this is a misrepresentation of the word "baxana" drawn from a work in Ramusio's *Delle navigationi et viaggi*, further confounded by other references mentioned below, e.g. the bezoar in n. 291.

[289] That is, the Roman Emperor's physician. The Emperor at his time was Claudius, whom Scribonius accompanied on his British campaign. Scribonius lived from approximately A.D. 1–50.

[290] Good against snakebite: "Habere ergo in cinctu oportet peucedanum vel cervi, cum captus, est, in oculi angulo, qui est ad nares versus, quae inveniuntur sordes virosi odoris; has Siciliae venatores diligenter colligunt et habent in cinctu propter ante dictam causam." "You should have in your girdle sulphurwort, or the slimy stinking dirt that is found in the medial canthus of the eye of a deer at the time of its capture. The Sicilian hunters carefully collect this and keep it in their girdle for the specified reason" (Scribonius Largus, *Compositiones* 163).

there is a highly poisonous root called bezar,[291] which kills instantly; its fruit is an outstanding aid not just against the root, but against any other poisons; the fruit is called nirabri. But how alexipharmacum[292] and poison can arise from the same thing is covered elsewhere.

Amethyst has the colour of wine, and is an attractive gem of low price, even though it is Eastern; it is believed to prevent inebriation [from its name in Greek: "without intoxication"] when attached to the navel, and (as we said above)[293] to stir up dreams. Coral[294] is not a gem; its kinds are shiny-white, reddish, and black, all to be seen on the same plant. The result is that they do not differ in age nor in kind,[295] but like the rest of the stones they are tinted by the sea's vapour; it is delicate, and arises like a bush at the bottom of the sea between stones and rocks. The most noble is red, and the red part that comes from it, like purpura,[296] sending forth a fiery brightness, powerfully strengthens the stomach if suspended vertically from it, an opinion which Albertus strives to attribute to Galen and Avicenna.[297] It is of slender substance, and is among the very slenderest things that grow in the sea, and therefore strengthens the limbs and tempers the spirits. Hence a coral that is as we said earlier it ought to be strengthens the heart and brain, cheers the mind, and opposes epilepsy. &474 But though its supply is very general, the supply of the best is very rare; items that are plentiful are easily disposed of,[298] and what is easily disposed of cannot be perfect. And so everything first-class must be rare. It solidifies and hardens with the air after being taken from the sea, since air (which is rarefied) dries up its moistness, and besides, cold condenses the parts. It is chilled by the air even in midsummer, because the part of the air that gets inside becomes chilled; it has been shown that air is chilled when it is dispersed. Hence Ovid wrote:

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291 The *bezoar stone*, which repels poisons, is mentioned by Cardano in chap. 6 of his *De arcanis aeternitatis* (*OO* 10: 12; on this work see also n. to Book I, at 5 [1560]). The bezoar was regarded as a concretion formed in the stomach of certain animals such as the goat or stag. See Adams on Paulus Aegineta, Book 7, sect. 3 (426–27). Cook (*Matters of Exchange*, 24, 191) also mentions bezoar as a concretion from the goat's stomach especially, imported from Persia and the Coromandel coast. What is here described in Book VII is a *root*, with poisonous properties, but the fruit of the same plant can function like bezoar stone.

292 See n. on "alexipharmacum" in Book II at 195 (1560).

293 At 448 (1560) above.

294 See n. 2 above.

295 "species."

296 Here evidently the mollusc from which Imperial Purple was produced in classical antiquity, or else its colour. At 455 (1560) this word "purpura" represents the colour of an amethyst.

297 The passages in question are identified in Nenci, 640 n. 95, and so Albertus succeeded in his attribution.

298 "absolvuntur."

> Even to-day coral retains this same nature, hardening at the touch of air; that which was a plant when under water becomes rock when brought above the surface.[299]

A property of the red, pure, and glowing coral, as of a carbuncle, is that if it is tied round the neck so as to touch the flesh, then when the person is ill or is soon going to be ill, or has drunk poison and is not yet aware of that, it turns pale and loses its sheen, so much that you would marvel, and I have noticed this more than once. The reason is, that the curious vapour, still unable to do harm to a person, upsets the more sensitive substance of the coral, an extraordinary experience.

These are the more noble and the more commonplace gems. But they are tampered with[300] by extraordinary methods, classified into three in number. The first of these is commonplace, that the colouring matter[301] is placed between two flat tablets of crystal with translucent glue, and then as these set, the gem is enclosed in a ring, so that the crack at the joint is imperceptible—and this method is commonplace and cheap.[302] A source[303] of these &475 gems, indeed a market for them, is this town of ours, in which the same skill is cultivated along with jewels.[304]

The worst swindle that is introduced, and no ordinary one for cheating, was originated by Zocolinus of our town, whom our prince ordered to suffer the appropriate penalty for counterfeiting coinage (though all the jewellers made a plea for him).[305] You can see the human ingenuity—and do accept from one body of people the evidence of the many; if I upset them, I am less ashamed and repentant than I rejoice at being detested by people of these habits. So that notorious man used to take a tablet of genuine stone, as if to make a carbuncle out of a carbuncle or an emerald out of an emerald—a shiny tablet, and cheap because of its [470]thinness and its being of dilute colour (there is a very large supply of

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[299] Ovid, *Metamorphoses*, 4. 750–752. Old and modern Latin texts differ here: the 1560 text here runs: "Unde Ovidius: Nunc quoque coraliis idem natura remansit, / Duritiem tacto capiantur ut ab aëre quodque / Vimen in aequore erant, fiat super aethera saxum." I have translated this but amended "erant" to "erat" and rendered "super aethera" as "above the surface." A modern text (Haupt) runs: "nunc quoque curaliis eadem natura remansit, / duritiem tacto capiant ut ab aëre, quodque / vimen in aequore erat, fiat super aequora saxum." The Ovid quotation first appears here in the 1560 edition.

[300] "adulterantur."

[301] "color."

[302] Agricola (cited by Nenci, 642 n. 99, and the passage is in the *De natura fossilium* 6, trans. Bandy, 116) points out how the fake is easily spotted by noting that the stone can be filed, and when dislodged from the ring, the joint is revealed.

[303] "copia."

[304] ". . . ipsa urbs nostra, in qua virtus eadem cum gemmis colitur."

[305] Nenci (642 n. 100) has identified records of the conviction in 1535 of one "Cocolino" or "Cocholino" for this offence.

them, as I said, and always will be, like the supply of people of these habits). And under that tablet he used to put a matching thick one of crystal, and linked the two as closely as he could, inserting the proper colour in between, for instance brilliant red for carbuncle, green for emerald, blue for sapphire, and to make the crack imperceptible, he used to close it with gold, thus removing any suspicion of a trick. It is in fact forbidden in our more distinguished towns to enclose a counterfeit gem in gold. In this deception nothing is needed except the vendor's good repute.[306] The crack lies hid in the gold, and because of its thinness the colour makes it bright; the upper surface, since it is of the right kind, reproduces the appropriate glint of the real gem. Thus this remarkable craftsman used to deceive even the jewellers themselves, until with the recognition of the deception, when he was planning his escape, he was condemned to exile by all the more distinguished &476 towns, and thus for a tiny amount of gold he betrayed our town's good repute everywhere; the theft is not to be disdained—a gem worth three golden crowns used to sell for three hundred very often, or even many more. So with the recognition of the deception, since a trouble-free path to excessive profit was removed, he switched to the notable invention of counterfeit coinage, and paid the penalty for that.

The third way of counterfeiting gems is much more distinguished and less condemned, technique struggling with nature. One gem is changed into another through the aid of fire. When a sapphire[307] with a gleam, but otherwise of dilute colour, is being linked to gold, the fire is applied gradually until the gold melts, the gold is very hot for three or four hours, then the gem is taken out and allowed to cool gradually—you will find a diamond. The gem actually remains, and is resistant to the file; whatever there is of blue colour is gone. This is why we hunt for sapphires of very dilute colour—they are cheaper, and turn into diamond more quickly, and are transmuted more completely. The man who first discovered that grew very rich very quickly. Then when the procedure[308] came to light, there is still profit left for the technique; the gem gleams a great deal, because sapphire is hard. There are people who out of aquamarine[309] (a cheaper and softer gem) make pretty diamonds. And there are people who do not bake a sapphire onto gold, but simply wrap it in chalk in a fire, and the venture[310] succeeds in the same way. Care should be taken that the fire is placed little by little round the cold gem, and the gem is allowed to cool down later when the task is done and the fire &477 extinguished—it is dangerous to extract it from the fire. It is a defect if any trace remains of the blue colour.

306 "autoritas."

307 On sapphire, see n. on "select sapphire" in Book IV at 316 (1560).

308 "res."

309 A sea-blue variety of beryl.

310 "res."

Carbuncles are counterfeited[311] by distilling orpiment, but apart from brilliance and colour, everything else is lacking. With more trouble, an emerald is made: crystal is very finely ground, Martiacocta[312] is added, and very bright verdigris, or vermicularis, and raw brick clay[313] is dug up, these three are put together, and roasted in a brick kiln among other items with a mark on it; then a lump like an emerald is taken out, it is broken up, and polished—it is glass, but so choice that unless those who first made the discovery (this is actually a new discovery, one of our own times) had wanted to enrich themselves too fast with big lumps, and thus created suspicion through their plentifulness and size, the deception could have gone unnoticed even now, to the vast and incredible enrichment of the discoverers—though they did make some profit. I have seen some so pretty that when surrounded with gold they outdid the native ones in brilliance. The best outcome is if they are totally without bubbles; bubbles reveal that it is glass, and make the stone paltry. A file bites into it,[314] since it is glass. In fact every gem with a smell of lead passes over into glass, especially when it has been reduced to a fine dust.

Furthermore, it is well known that lead is contained in Martiacocta. Martiacocta consists of chali salt,[315] alum, and sand, then of black or white lead reduced into limestone;[316] potters' vessels are dipped in this, and when placed in kilns take on the glint of glass as well as its solidity—they do not actually absorb the contained &478 moisture or pass it on. The greatest success occurs in some potters' vessels of Germany, which are like this of themselves simply because of the earth. And so Martiacocta and gems with an odour of lead pass over into glass, yet pick up a colour; they do not stop being gems because of fire alone, but they lose colour, they do not pick it up. So if some midway procedure is found through which a gem picks up colour, and also gets soft, but not enough to pass over into glass, then enormous profit will accrue. It is desirable then to make it less soft than lead, and more than fire alone would do; thus sapphire will actually be able to pass over into carbuncle, being harder than carbuncle; and if it turns out more soft, into emerald, by the addition of green colour. Again, carbuncle can change into emerald, for it is far harder than emerald, even if quite a lot softer than

311 "finguntur." This sentence first appears in 1554.

312 "Martia cocta": Nenci (644–45 n. 102) cites Biringuccio to the effect that this is a mixture of items such as gravel or sand, alum from dregs, or tartar, and other ingredients such as lead, suited to create a glaze on ceramics. The same word appears again at 855 (1560) in Book XII of *De Subtilitate*, in the phrase "vel id excrementum quod ex martiacocta vasorum accidit simile vitro contritum . . ." which appears to indicate a residue like ground glass from the heating of such a mixture.

313 "later crudus."

314 "tangitur enim lima."

315 On chali, see n. to Book V at 379 (1560).

316 "calx."

sapphire. Then there are many procedures of this kind that are certainly capable of making their inventor's fortune and remaining undiscovered; where there are extremes is where a midway procedure is essential.[317]

I recently saw one surface of a crystal perfused with blue in such a way that it was not dissolved away by water and could not be scraped off with iron. A useful discovery, if it is spread over by continuing the operation.[318] Indeed, when a colour that suits the gemstone is produced, it never deteriorates. And if enclosed in a ring, no technique can reveal it, since the colour that shows is just like the natural one, though distributed only on the surface that shows;[319] it is distributed by fire. Furthermore, among the kinds of glass that are made from Martiacocta[320] and crystal, if a red colour is added, a carbuncle emerges—if a blue one, a sapphire—but they are all less precious than &479 emerald, because they differ more from the nature of those gems than glass does, which imitates emerald; there is in fact no gem that is not harder than emerald, as we said above. This is why it is emerald alone that people are always trying to imitate, because of its great softness; but these are also made in a brick, like counterfeit emerald.

But what some people say is extraordinary: that baked bricks are heavier than they were before being placed in the kiln. The reason can be that where they are made, they are dried in the Sun, and take up a significant amount of [471]air,[321] which lurks inside and makes them much lighter; when they have been fired[322] and with the air driven off, they are made heavier, although the moisture has been removed. For if they are baked more than is right, they turn out like iron in colour, weight, and hardness; but since they become smaller, I am compelled to rely on the authority of Leonardo Iacchino.[323] Whether the smallness really happens, the explanation of weight and colour can be the same—smallness in proportion to the matter, but the smallness itself occurs to something forcibly compressed, and with melting of the earth retaining something metallic; whence

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317 The following four sentences first appear in 1560.

318 Thus covering it all over.

319 "adversa."

320 See n. 312 above.

321 Text divergency in the rest of this paragraph is considerable and is set out in detail by Nenci, 646–47.

322 "excocti."

323 Leonardo Iacchino, Professor of medicine at Pisa, and author of *Quaestionum naturalium libellus*, published at Lyons in 1540. He is mentioned in Robert Burton's *Anatomy of Melancholy* (Bk I, sect. 2, memb. 2, subs. 4 [ed. Dell and Jordan-Smith, 206]) for the observation that "the blood is much blacker to many men after their letting of blood than it was at first." Nenci (646 n. 105) has identified the passage in the *Quaestionum naturalium libellus* of Leonardus Iacchinus, published at Lyons in 1540, but even there, no measurements of weight are mentioned.

almost always things are distorted when over-baked,[324] and curve inward. It is a point worth much questioning, why it is that when the fire is interrupted in kilns, the bricks break in a brief moment. This does not always happen, but when excessive heat is diminished with the quenching of the fire, it breaks the bricks. Accordingly, when it is kindled afresh, it also breaks them; when things that are dry are warmed with fresh heat, they burst, as is well known in the case of glass. &480 The reason is that before something hard melts and softens, it is burst by the inflation distending it. So there is much loss of pottery through this imbalance.

To return to my original plan: technical skill does not manufacture fake gems only, but also stones and whetstones. From emery[325] came the first whetstones that abrade gems, also geodes from geodes,[326] and whetstones of their own sort out of other whetstones. Individual ones of these are finely ground so long as there is an inclination to make something of this kind, and are treated with white of egg, linseed oil, and juniper gum,[327] and dried under sand. A mosaic[328] is also made, which embellishes temple pavements with figures of people, of wild beasts, and of trees, as at Constantinople in the temple of Wisdom,[329] at Venice in that of St Mark, and at Florence in that of St John the Baptist; walls too are embellished, as at Milan in the temple of St Laurence, with fragments of stones of varied colours—matt-white, red, blue, green, black, bonded together with sticky glue, so that the figures reproduce not just the form but also the colour. A permanent grout[330] is made for this work from lime and pork fat or pitch, or white of egg; this is particularly resistant to water, hence it is used to join together gutters[331] for conducting water. Another excellent one for the same purpose is made from lime, white of egg, oil, iron filings, and sea shells;[332] but

[324] The text here is tortuous and obscure, and in particular, "excocti" appears at this point, making difficult the translation offered, since "excocta" would be expected.

[325] "Smiris": see n. to Book II at 131 (1560).

[326] "ex geode geodes"; the stone is previously mentioned in Book VI, 414 (1560), where see n. on it; from the mention there, it may be suspected that here "ex geode Aetites" should be read, the phrase in the corresponding passage of Agricola cited here by Nenci (647 n. 106)—but Cardano wrote in the passage in Book VI that he did not believe in the identity of Aetites and geodes.

[327] "iuniperi lacryma."

[328] "Lithostroton."

[329] Holy Wisdom, more precisely—clearly the Church of Hagia Sophia is meant, since the phrase "Hagia Sophia" means just that.

[330] "Maltha."

[331] "canales."

[332] "marinis umbilicis"; *OLD* interprets this phrase by a citation from Cicero as meaning "sea pebbles," while *L&S* from the same citation and two much later ones offers "a kind of sea snail, sea cockle." I regard the shell of the latter interpretation as more likely to be Cardano's meaning here.

the gutters themselves are made from timber of fir or elm or spruce or piceaster; these timbers have a very fatty and hot moistness, so as to be highly resistant to attack from water. And some are made from lead, but the best (and everlasting) ones from copper. It can be taken as a guiding principle[333] &481 that everything that fire has consumed more than is normal,[334] such as coals, copper, sulphur, is never damaged by water, even if lying in it for thousands of years. But for linking stones or fragments of marble, a grout is enough, made from marble dust and white of egg or pitch. So it is evident why some things stay undamaged in water, and which they are; but others are so compact that they are barely liable to water damage, yet in them the outer layer[335] gets destroyed.

Let us return to the account of gems and leave this behind. Since plenty has been said about those that grow underground and in water or between stones, we must now deal with those that are generated[336] in animals. And though it is believed that real gems can be found in animals, right up to to-day I have never seen any real gem extracted from the body of any animal. These should be entirely uncommon, because they solidify through cold. The evidence that gems solidify through cold is, firstly, that they arise between stones and in extremely cold places. Then, that they are actually preserved by cold, and are weakened and spoiled by heat; watery substance glitters only if solidified by frost, for instance in ice; but all gems glitter, and most are also translucent. They also soften in fire, so much that they can be pierced, like diamond—other gems do so more, some even melt. Hyacinth softens and melts, but with great difficulty; crystal does so easily. And from the coldness of all stones comes irrefutable evidence—&482 and if it is not enough, touch itself provides more. So if stones solidify with cold, and gems, being harder, with greater cold, it is not remarkable that gems are not generated in animals, where there can be nothing very cold.[337]

But if some stone is generated in any circumstances, as the Alectorius[338] is—if it is a gem or has powers, it cannot be devoid of life. Because a gem is in fact harder, and not touched by the file, it cannot solidify with heat. And whatever cannot be entered by cold must be alive. So no hard gem can exist in an animal, for it could not be nourished by a humour as liquid as the sort that is secreted in an animal—as a gem was not soft, neither was a stone. So from the start the gem must be alive, through spirit and humour, and be soft for that

333 "regula."

334 "iusto."

335 "cortex."

336 "nascuntur."

337 The following paragraph first appears in 1554.

338 The word is derived from the Greek word for a cock, and as Cardano soon remarks, 485 (1560): "I do not think it possible that a genuine Alectorius is completely generated in the gizzard [*ventriculus*] of a cock or farmyard cock."

reason. Then it grows gradually through heat, its life being made torpid,[339] as a uterine mole is, till it gets so hard that it can grow no more, and then solidifies through cold, until it is taken out, or is released by the animal's death—during its life, the gem cannot be finished off and completely hardened.

As I am aware, the most expensive of these is the pearl, which is formed from rounded surface layers.[340] The more noble ones are generated from round shellfish, but are less round than the shellfish. Others, not noble, are rounded from an oblong shape, as if contrariwise. The striped kind of shellfish produces both while spending time at the bottom of the sea. And so it is a fable that they conceive them from the dew of heaven.[341] There is a second-rate[342] kind of pearls developing from mother-of-pearl,[343] which is what long oysters are called, but I would do better to call them shellfish, since they are striped. A pearl &483 ages very fast, differing from stones in this feature. The north Indian sea exports them near the island of Cubagua,[344] beside south Tararequi,[345] and they come into being in numerous other places too. The main excellence is in their whiteness, brightness, and roundness. It is found in shellfish or oysters close to Britain, more often in the Indian sea. In a single shell[346] there are very many pearls, especially the smallest ones, so that their supply is beyond belief; big ones are rare; ones that are free of blemish are very rare—they cleanse the blood, and have a rarefied substance. Their colour is like a pseudo-opal's, [472]in changing with the way you look at it.[347] The reason has been mentioned already: pearls consist of layers, which are polished on one surface and rough on the other. Try a test[348] with a number of mirrors joined together in the same order, so that the shiny surface of one covers the rough one of another. Then, if you have made them small and thin enough to create only an unbroken rough or varied body, you will end up appreciating the reason why the setting of the point of view[349] alters the colour and brightness. A pearl's colour is mostly shiny-white, glittering, moderately dusky;

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[339] "hebetata."

[340] As Nenci notes, Pliny (*Nat. Hist.* 9. 108) mentions pearl fishing, and Oviedo (*West Indies*, 115–18) has an extended account of the pearl fishery.

[341] This tale is however in the Pliny passage (see n. 340 above).

[342] "ignobile."

[343] "nacarones."

[344] Island off the coast of Venezuela, west of Trinidad, between Margarita ("Pearl") Island and the mainland (see Oviedo, *West Indies*, 124)

[345] Nenci (652 n. 112) has identified the relevant passage of Oviedo; in the *Glossary of Place Names* to Oviedo's *West Indies* (127) it is called "the largest of the Pearl Islands in the Gulf of Panama, now known as Isla del Rey or San Miguel." And Oviedo (117) mentions a pearl of 31 carats that came from this Island.

[346] "theca."

[347] "Sed colos eis ut pseudoopalo, scilicet qui ex aspectu mutetur."

[348] "experimentum sume."

[349] "aspectus ratio."

they take it over from their shells.[350] It is not unlike the snail-shells which India (so they say) exports. As I have often seen them, I can speak about their colour, form, and substance—I cannot speak adequately about their origin. There exists the shape of a trireme with a tall stern, in which there is another small container (you might say a cup contrived by nature, for the size of the one I saw is right for holding a small cupful)—a thing really of the most choice usefulness and &484
beautiful shape—it is accepted that this is a Nautilus. This object is the shell of a snail, very like pearl shells, as much more noble than our snail shells as the Indian air and earth, also water, excel our elements; things get better over the passage of many centuries.[351]

Borax[352] is found (so they say) in the head of an ancient and large toad. Brasavola[353] describes having found it in this animal's head, and that it is more of a bone than of a stone.[354] It is twofold: hollow and very like a bone, of a pale dusky colour, and another which holds the stone in a bone. But as Brasavola reported, the head bone is one that solidifies with age, because it is nourished by earth. But I do not know its powers; people think it has power against the stone,[355] but I am not sure whether it prevents the generation of a stone—it cannot entirely prevent it, nor the whole of it; whether someone can slow it down is open to doubt.

Limacius stone is usually generated in the head of a snail, which is not covered over by a shell.[356] As I can show, it ought to be of a shiny-white colour and a rough surface, because it has been congealed by cold out of watery substance, which leads to its being small, having been found in a small animal. They say that when tied on to patients with a quartan fever, it did considerable good. In the perch,[357] a small fish, which is called the "raven" because it has a large head, two stones are found—shiny-white, oblong, flat, on one side looking

[350] "hunc à suis conchyliis mutuantur."

[351] The implication of this remark is interesting, that India's elements are superior to those of Europe, since India is an older country.

[352] The translators of Agricola's *De natura fossilium* remark (54 n.) that it is an artificial mineral (a hydrous sodium borate), and that Agricola regarded it as related to the hydrous sodium carbonates which he called "nitrum." He also regarded it as related to chrysocoll (on chrysocoll see n. to Book II, at 213 [1560]) but (*De natura fossilium*, Bk. 9, trans. Bandy, 197) as a substitute for it. Castelli says it resembles a kind of nitre, and its name is close to the Arabic *Baurac*, but "it is not known from what it is made, nor how. At Venice they make it from some burnt white stone and call it crude borax."

[353] On Brasavola see n. to Book II, at 142 (1560).

[354] Nenci (653 n. 114) has identified the passage.

[355] "calculus": a bladder stone, not a gemstone. But immediately Cardano uses "lapis" for the same sort of stone.

[356] "cortex."

[357] "perca."

toothed—which are believed to benefit lithiasis.[358] It also helps gouty pains, so it is said, and the more so the larger it is.

&485 Stones arise in animals in two ways: one is by cold, as in the snail, perch, crab, toad, and (so they say) in Indian tortoises. The other way is by heat, as often in the gallbladder of bulls, and sometimes in that of human beings; a stone was found a few years ago in the gallbladder of a person suffering from the kind of scabies referred to as "lepra." It is generated in the bladder, and in the kidneys, to their great harm. I possess one that developed in the lung of an ox, smooth, and of an ashy colour. All the stones that are generated in crabs, snails, and fish, as in the corvus,[359] manatee,[360] and numerous others, prevent the generation of stones in the kidneys, and dissolve any that have been generated. These stones actually grow in these animals through excessive cold; so when drunk[361] they chill the kidneys; but in human beings stones are generated through excessive heat; the matter for stones is like that, and very cold. It is therefore agreed that it also provides prompt assistance for excessive urine flow, which occurs either from the colour of the kidneys or their dryness. They relate too that in the cock's stomach the Alectorius stone is generated, so to speak a "cock's stone."[362] But a sard or agate is fashioned, in which a flame-coloured patch can be seen.[363] I do not think it possible that a genuine Alectorius is completely generated in the gizzard[364] of a cock or farmyard cock.[365] For since the gizzard of cocks is very capacious and always full of refuse, this critical[366] humour cannot distil gradually, nor gather together nor solidify. If it is to solidify, that will rather happen in channels[367]—but thus the stone would be tiny. It could not stay entirely at rest till it solidifies. &486 It is evident that stones are generated in the liver, because its channels are narrow, and its flesh compact. And Georgius Agricola reports that a huge one was found in a cock; it was of incredible size, matt-white, and tawny, and dusky at the point where the liver protrudes; like pumice-stone on

[358] I.e. stone in kidney or bladder.

[359] "Corvus" here is evidently not a crow but a fish. The word was mentioned just above as a synonym for "perca," the perch.

[360] "manati"—not a classical Latin word, but Castelli has it: a cetacean fish of the Indies, provided with hands, and called the marine ox or cow; he gives citations. Evidently the manatee.

[361] I.e. the stones, no doubt powdered.

[362] On this stone see n. 338 above.

[363] The following five sentences first appear in 1554.

[364] "ventriculus."

[365] "galli aut galli gallinacei"—the distinction is not at all clear.

[366] "ille."

[367] "meatibus."

the lower side, a feature far removed from the nature of a gem; an inch[368] long, a finger wide, half an inch tall.[369]

In the gizzards of cocks, however, gems are found which they have happened to swallow; they are pretty enough, since they are cleansed by the gizzard's heat, and acquire a sheen—indeed, jewellers put pearls before pigeons so as to get them polished. So is it any wonder that harder gems are polished in a cock's stomach, with a longer spell there and sturdier heat? Whether there can be a gem in the liver is uncertain—the heat of birds is greater than the heat of quadrupeds,[370] and their humour more rarefied. Stones are found in other parts of animals, such as in the upper joint of a lobster's claw, and I found one once. One of our colleagues found a smaller one, and I am in possession of both. The colour is mixed white and red, smooth and gentle. The largest ones do not exceed the size of a pea,[371] indeed do not equal it. The shape is that of a milica[372]—indeed, you might think it an actual milica if you did not know them, as it has nothing in common with the little stones found in crabs' eyes. Their scarcity makes finding them serve as an omen. Also found in animals are things like stones, yet that are not stones, such as the egg of an ox. This is in fact found in the ox's stomach, the size of a goose's egg, of a rusty &487 colour, very light, and very smooth. It is put together from the refuse of its food, and movement gives it roundness, while phlegm holds it together. Hence if it is broken, it is seen to consist of hair; it is hard in proportion to its lightness. Nature plays such tricks that sometimes even oxen bring forth eggs.

There are stones that are included in the list of gems, though falling far short of that—for instance the geodes, which people erroneously call aetites,[373] because "it is pregnant."[374] The rusty one is imported from Gallii, the pale one

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[368] "uncia," about 25 mm. This whole sentence first appears in 1560.

[369] The following paragraph first appears in 1554.

[370] This is true; the body temperature of birds is around 40°C, in contrast to mammalian body temperature around 37°C. The recognised Galenic organ of measurement was the human hand, and only right at the end of the 16th century was a device to measure relative (not absolute) temperature devised by Galileo; see S. J. Reiser, *Medicine and the Reign of Technology* (Cambridge: Cambridge University Press, 1978), 110. Though birds are feathered and their skin temperature hard to assess, when they are brooding eggs the feathers are absent below, and hands picking up the bird would touch bare skin.

[371] "granum pisi."

[372] The meaning of this word has not been identified.

[373] On geodes and aetites see n. 326 above.

[374] This remark is attributable to what Pliny says (*Nat. Hist.* 10. 12) about the aetites stone: "est autem lapis iste praegnans intus alio, cum quatias, velut in utero sonante."—it is a stone that is pregnant with another stone inside. When you shake it, the one inside makes a noise as if it were in a womb.

from Cannae in Italy. The tecolithos is double—as if you were to say, "stone-breaking"[375]—it is Indian,[376] and is what Agricola calls the sponge stone.

Features of marbles that are closest to those of gems are their ornamental value,[377] beauty, and [473]attractiveness. Their more respected[378] kinds are phengiticum,[379] Parian,[380] zeblicum,[381] porphyrites,[382] and ophites.[383] They are all commended or criticised for colour, sheen, hardness, and translucency. Phengiticum shines the most, and reflects images. Thus Nero completed inside the Golden House[384] the temple of Fortune which Servius Tullius had started long before,[385] and called "Seia"[386]—in such a way that it was built inside with this kind of marble, picking up light with the doors closed all round so that daytime brightness seemed to have been preserved there. Zeblicum is found in Meissen, and is believed to be good against poisons—I do not know whether it does help, but that it can help is certain, since it is quite soft; if we eat and drink out

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375 See n. to Book II at 132 (1560); "stone-breaking" is what tecolithos means as Greek.

376 But although "Indicus" stands in the text, Nenci (656 n. 119) adduces a passage from Agricola linking the tecolithos not with an Indian stone but with the "Iudaic" stone, which Agricola says has various names.

377 "gloria."

378 "nobiliora."

379 phengites, φεγγίτης, probably a kind of onyx marble (see Pliny, *Nat. Hist.* 36. 163).

380 Paros is the second largest of the Cyclades Islands in the Aegean Sea, and celebrated for the quality of its marble since classical times.

381 Nenci cites here Agricola, *De natura fossilium*, 7. 315–316 (trans. Bandy, 154–55), to the effect that zeblicum (a sort of marble) is used for spoons and cups that are thought to resist poisons, as well as for the balls on which women dry their headscarves. Scaliger (*Exercitatio* 126 [441]) does not agree that zeblicum is a marble at all: it does not glint, and is not hard..

382 Same as "porphyry": a hard rock of purple and white colour, long used in sculpture.

383 'Οφίτης means "snake-like" in Greek, and this is a stone with snake-like markings (Pliny, *Nat. Hist.* 36. 55). "Ophys" is mentioned in Book VI at 416 (1560).

384 This (*OCD*) was the name of the residence Nero built after the great Rome fire of A.D. 64. A. Boëthius (*The Golden House of Nero* [Ann Arbor: University of Michigan Press, 1960], 105) refers to "the marvelous temple of Fortuna of the Domus Aurea, built of translucent marble (phengites, Pliny, *Nat. Hist.* 36. 163)." Nero rebuilt it with this stone, which made it as light as day in the temple during the day, even when the doors were shut.

385 This is mentioned by Plutarch (*Roman Questions*, ed. H.J. Rose [Oxford: Clarendon Press, 1924], question 74), who asked why Servius Tullius, an early king of Rome, had built such a shrine, and speculated on the answer.

386 *OCD* indicates that this was "an obscure goddess" and no connection with the present topic appears there.

of vessels made of hartshorn, the cups and vessels will after a delay as a rule inhibit[387] the powers of poisons in them, but not all.

The sorts of Parian marble are very numerous, &488 distinguishable by colour. The shiny-whitest one, which is discerned everywhere in Italy; the ashy in the district of Hildesheim, which is in Germany; the green, as in the temple of St John the Baptist at Florence. The iron-like one[388] on which at Stolpa[389] the Bishop of Meissen's stronghold is founded—it is of such hardness that Agricola mentions that at Meissen the smiths make anvils of it;[390] he says that it clearly needs to be tenacious, and of more rarefied and more compact substance, and consequently be heavy as well. There is also a shiny black one, brilliant and glittering, from which is made the tomb of Cardinal Caracciolo (a man of exceptional integrity, and director[391] of our province),[392] in our great church, established at the right side of the altar. And there is a variegated one of various kind, which is generally fragile, and breaks spontaneously, so that parts of it are not fully developed,[393] and parts are over-fired. There is also a dull-red marble. Why go on?—every colour has appeared in marble.[394] At Siena above the altar, seven kinds of Parian marble can be seen together (I call it Parian, in the way that one calls copper Corinthian; it usually is given the island's name, for being very beautiful):[395] shiny-white, ashy, dull-red, green, shiny-black, porphyritic, and ophites. And there is a porphyritic marble marked with reddish and (as it were) shiny-white patches—or rather, reddish with patches glinting in between.[396] There are two fine columns made of this at Milan in the temple of St Ambrose before the altar, and also the tomb of St Dionysius,[397] which was transferred to

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387 "hebetabunt."

388 "ferreus."

389 In Saxony near Dresden (*Orbis Latinus*).

390 Agricola, *De natura fossilium* 7. 309–11; trans. Bandy, 149.

391 "praesul."

392 Nenci states that Cardinal Marino Ascanio Caracciolo (1469–1538) was the most important representative of imperial power over the dukedom of Milan when Cardano returned to Milan (which was on 3 January 1553: Wykes, *Doctor Cardano*, 138).

393 "crudus," the reference presumably being to the process of development that Cardano envisages for stones and gems.

394 "Nullus color marmori concessus non est."

395 I.e. presumably doesn't necessarily actually come from Paros.

396 Nenci cites Agricola, *De natura fossilium*, 7. 311 (trans. Bandy, 150), where it is suggested that this is of Egyptian origin. Indeed, it came from a single quarry in the Eastern Desert of Egypt. See V. Maxfield et al., *The Roman Imperial Quarries* (London: Egypt Exploration Society, 2011).

397 St Dionysius of Milan was Bishop of Milan, strongly opposed the Byzantine emperor Constantius II, and was exiled to Cappadocia in 355 A.D., where he died about four years later. Cf. PL 16. 790An.

the great church of our town—a tomb as big as a human body, and of significant thickness as well.

&489 Ophites[398] is green, and usually marked with dull-white patches all over, and also patches of some other colour. I have often seen pillars and tables of it; likewise, there is a table of it and of another kind of diverse colour at the establishment of Andreas Alciati, which is of more than ordinary beauty.[399] In Parian marble, shapes made conspicuous by the diversity and combination of the veins are found, which reproduce a likeness to hold its own with a painted one. For instance, in addition to others, in the church of Holy Wisdom at Constantinople is an image of St John the Baptist clad in camel hide, which is utterly perfect in every detail, except that one of his feet is not as well portrayed as a picture can.[400] We have already mentioned that the reason for this is a chance cause, not one of its own.[401] There are also kinds of marble from a renowned region, like Numidic; this being in fact made from a very subtle teardrop, is very brilliant on account of the region's heat and shines greatly—and can be easily carved because of its softness and evenness. Flint and whetstones cannot conveniently be carved, because they consist of thicker parts. And so even to-day, Numidic marble is the most sought after.

One of the kinds of marble is alabaster, translucent, and usually shiny-white, from which small boxes[402] for perfumed ointments are made; it is sturdier than glass, purer than metallics, it is good for pottery, because it absorbs or exudes[403]

[398] See n. 383 above.

[399] Agricola (*De natura fossilium*, 7; trans. Bandy, 152) refers to three varieties of ophites: the white, the black, and the grey. He does not mention *green*, although the translators (230) describe ophites as "green, metamorphic and altered igneous rocks," and green mottling appears nowadays to be an accepted feature of ophites! Nenci (659 n. 126) mentions that Andrea Alciati (1492–1550) was for some years professor at Pavia (1533–1537 and 1541–1542). He was Cardano's "staunchest friend there" (Eckman, *Jerome Cardan*, 48), and the great jurist of his age, a very early exponent of Roman law. Cardano wrote a biography of him (*Vita Alciati*, *OO* 9: 568–69; Maclean, *De libris propriis*, M138 [107]).

[400] Nenci cites Agricola (*De natura fossilium*, 7. 312; trans. Bandy, 151) who writes that there are twin bas-reliefs ("cruste") representing this, and that the Turks show them off to Christians. The Bandy translation appears to err here; the original runs, "eas Turcae etiam ostendunt Christianis," but the translation runs, "the other shows Turks with Christians." There is indeed a John the Baptist figure in the Deësis ("Entreaty") mosaic in Hagia Sophia.

[401] "causam . . . fortuitam, non propriam." The remainder of the paragraph first appears in 1554.

[402] "pyxides."

[403] "remittat."

less of the ointment, and so its use is essential.[404] Because of the translucency it thus acquires when submerged in water, it absorbs and exudes juices more, for a reason we have mentioned above.

&490 Whetstones come next to marble; the more notable of these are from Lydia and Damascus. The Lydian one—shiny-black, quite rarefied of substance, glinting—reproduces with wonderful subtlety the colours of metals; goldsmiths are helped by it to identify the purity of gold and silver; because of its rarefaction it does not create damage, so that you can assay a thousand times without even sacrificing one grain; through its blackness it shows up the metal's colour, because blackness concentrates[405] a sheen and colour. What whetstone has to offer[406] is to remove very fast, little by little, and everything, without being itself removed. This is why those from Damascus are the best—as well as actually abrading steel (however hard) very fast when rubbed on it, they are themselves slowly and minimally abraded, but as time passes, they do themselves disappear and get used up, by long and repeated friction: too much so in the case of poor quality ones, soft ones, friable ones, venous ones, ones with knots, ones too rough.[407]

Among the kinds of whetstone there is a soft stone from which at Como vessels are made for cooking food; it is delicate, so that it can be carved, and yet is of sluggish moistness, so that it has prolonged resistance to fire. It is of an ashy and darkish colour.[408] It is a property of all whetstones, but especially of the Lydian one, that those on the upper side are best, because they are brought to perfection by the Sun—the worst are on the under side, because they lie on the earth and the moisture[409]—those on the sides are usually significantly harder.

Thinking of the whetstone led me to remember the razor.[410] There is in India a stone of tawny colour, translucent, which splits things as a razor does; it is reasonable for glass and crystal to outdo a steel razor, because of their thinness. But what people go on to say is remarkable, that it is not sharpened by a whetstone or millstone or other stone, but just by water. This &491 occurs because of the thinness of its substance.[411]

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404 Pliny (*Nat. Hist.* 36. 60) mentions some of Cardano's points here about alabaster.

405 "colligit."

406 "Cotis dotes sunt,."

407 Nenci records here the difficulty in substantiating Cardano's admiration for the whetstones from Damascus by any reference in the works of Agricola.

408 Pliny (*Nat. Hist.* 36. 159) mentions some of the points made here by Cardano on the stone at Como, and he includes its green colour.

409 "humori."

410 "novacula."

411 Nenci (662 n. 133) has identified Cardano's source here as Petrus Martyr de Angleria (1457–1526), *De insulis nuper inventis, et de moribus incolarum earundem*, ed. in *De rebus Oceanicis et orbe novo decades tres*, 71a, very much to the same effect. On Petrus Martyr see n. to Book II at 127 (1560).

Onyx[412] has the shape of a point rather than of a sword, and not sufficiently well prepared,[413] if they are all like those I have seen.

Closest to marble and whetstones, but of thicker substance, is flint, itself of diverse kind, delicate, hard, tenacious, friable, heavy, smooth, impervious to fire, and passing over quickly into ashes, flaking,[414] red, and also of diverse colour. Flint is flaky, resistant to rain and cold; it usually melts,[415] and ends turning into ashes—the rest of the stones [474]for the most part pass over into lime.[416] The Nuremberg flint hardens when extracted from the mine, while the other kinds of flint are more inclined to break. And there is a stone similar in nature to marble in being capable of being cut, but ashy in colour, and of incredible softness, so that it is cut with a saw to work it, just like wood. There is a supply in the region of Venice. But because its colour is dim and does not provide a sheen, it can be regarded as flint. The properties of all flint are to be flaky, and not completely smooth, just as marble has its sheen like marble, and its ability to be cut. But this stone lacks one item of each of these: it has no sheen, so it is not marble, and no flakes, so it is not flint.

For the rest of the stones there is one word—rock—but six kinds: one kind is derived from the property, as taken from the lodestone, one from the powers, as in the case of the calamochus,[417] one from the colour, as in the case of the amochrysos,[418] one from painting, as in the case of the alabandicus,[419] one from the shape as in the case of the trochites,[420] one from distinctive resistance to fire or water, as in the case of magnesia. So we will start from the first kind.

&492 The lodestone or Herculean stone appears to be of two or three kinds: there is a rust-coloured one, and a shiny-white one; and a shiny-white one

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412 On onyx, see n. 8 above. This sentence first appears in 1560.

413 "neque satis affabre."

414 "squalens."

415 "but only in the hottest furnaces"—Agricola (*De natura fossilium*, 7; trans. Bandy, 157).

416 On the nature of flint ("silex"), Nenci (663 n. 134) compares Agricola *De natura fossilium*, 7. 318; trans. Bandy, 156–57.

417 More correctly, "calamochnus," a deposit or efflorescence of salt on reeds (*OLD*, citing Plin. *Nat. Hist.* 32. 140).

418 Correctly, "ammochrysus" (ἀμμόχρυσος = golden sand); it is mentioned by Pliny (*Nat. Hist.* 37. 188), who gives this derivation. Agricola (*De natura fossilium*, 5. 260) says that it is more of a sand than a stone, of a golden colour (and not just sand mixed with gold, as Pliny had said). Agricola's translators (95) identify it as *phlogopite*.

419 Alabanda was a town in Caria in Asia Minor, and Pliny (*Nat. Hist.* 37. 92) refers to a kind of carbuncle originating there.

420 Castelli says it is a stone like a wheel, and children bowl it along. Nenci cites Agricola (*De natura fossilium*, 5. 261; trans. Bandy, 97), where information similar to what Cardano gives appears, but in more detail.

marked with slight thin rusty veins, but smooth almost all over.[421] The lodestone of the rust-coloured kind has two powers, to start with, which almost every age has known: it attracts iron, and a piece of iron smeared with lodestone attracts another piece of iron, so much so that sometimes a lodestone has been known to attract five or even more rings in an unbroken chain. After that very ancient period in the epoch of Aristotle, if Albertus is to be relied upon,[422] it became known that there were two kinds of lodestone: one that directs iron to the north, the other that directs it to the south. This is how it is: a thin piece of iron is rubbed at its point against a lodestone, then it is hung up in equilibrium, then the iron rotates of itself, in such a way that the point faces north or south. These four points were already known in antiquity. But it was also known in the time of Albertus that there is a kind of lodestone which is called theamedes,[423] a variant of the normal lodestone,[424] a variant that repels iron. It is also the case too that a lodestone is attracted by iron, and that its power penetrates bodies, so that it attracts iron to itself even with a panel[425] in between.[426] So a great deal was known long ago which a number of people in our own time thought they had discovered; people credit one Flavius with the theory of the marine compass,[427] which it is agreed was known at least before the time of Albertus Magnus. He recalls it, but I could not believe that the use of the compass was known to Aristotle,[428] nor &493 that iron could point towards the north, when Galen and Alexander of Aphrodisias[429]—who overlooked no natural miracle, even a little

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[421] Here what I have translated as "slight" and "smooth" are both "levis" in Latin, which has two totally different meanings, so one has to guess which might be meant in each case. Another problem here is that Agricola (*De natura fossilium*, 5; trans. Bandy, 84) does not agree; "Lodestone varies in colour being either black, bluish black, reddish black, and sometimes even dark red."

[422] Nenci (665 n. 138) quotes the reference and discusses the difficult interpretation of the passage immediately following here.

[423] The Plinian passage (in *Nat. Hist.* 36. 130) from which Albertus and Cardano drew this remark is now regarded as an interpolation.

[424] "ipsi magneti."

[425] "tabula."

[426] Nenci points out that this phenomenon was noted by St Augustine (*De civitate Dei*, 21. 4. 4) and by Agricola (*De natura fossilium,* 5. 250; trans. Bandy, 84). Agricola wrote of lodestone placed in the panels of the ceiling of an Egyptian temple, and it held up a brass statue with some iron in the head, so that it was suspended in mid-air.

[427] "Pyxis." Its invention for marine navigation was wrongly attributed to one Flavio Gioia of Amalfi, and this issue is discussed by Nenci (666 n. 141), who attributes its inception to Lilius Gregorius Gyraldus (*De re nautica libellus* [Basileae: apud Michaelem Isingrinium, 1540], cap. 1, 5–6).

[428] This statement first appears in 1560, but its gist appeared in the earlier editions, with criticism of Albertus for mingling truth and error.

[429] On Alexander of Aphrodisias see n. to Book II, at 117 (1560).

one—did not recall such remarkable and useful phenomena. It is also accepted that in the time of the Romans they were unknown, and the Romans suffered so many shipwrecks for this reason—hence their strength was impaired more than once during the Punic Wars, and Octavian's fleet was scattered against Sextus Pompeius.[430]

So let us approach once more the powers of the rust-coloured lodestone, then explain their basis, starting from experience. A lodestone, then, attracts iron, and it attracts steel too. Girolamo Fracastoro[431] also recounts that he has seen it attract silver—in general it does not attract silver at all.[432] The reason that it attracts iron is that that is its food, since as I have said, stones are alive, and therefore a lodestone is best kept in iron filings.[433] So what is extraordinary about it attracting steel, in which the major part is iron? But if the iron is touched first by the lodestone, it is more easily attracted—either the silver contained some iron, or there was a different kind of lodestone, about which I have decided to say nothing, since I know nothing about it. But this does meet our principles, that silver and the other metals can be atttracted by a powerful stone if they contain some iron. A lodestone does not attract all over, but where it has a thin outer layer, and more at one part than another, and shiny iron more than iron sunk in rust. And, contrary to the fables, it is not obstructed by garlic or onions, much less by diamond—unless maybe so slightly that it is detectable only &494 in tiny and weak things, and in the rest escapes notice.[434] Iron that has been rubbed with the stone not only is attracted more quickly by a lodestone, but attracts another piece of iron more easily to itself than the stone itself does. The power of a lodestone appears actually to be reinforced by iron—the slenderer

[430] Nenci, 667 n. 142, provides references to accounts by the historian Polybius of such disasters during the Punic wars, one (1. 37) "so terrible a disaster that it is difficult adequately to describe it owing to its surpassing magnitude," and another of lesser import (1. 39. 3–6), by Appian of Octavian's disaster (*De bellis civilibus*, 5. 81–90).

[431] Hieronymus Fracastorius (1483–1553) was an Italian physician and poet. He practised in Verona after studying at Padua. He attributed the spread of epidemic diseases to tiny particles that could transmit infection by direct or indirect contact, even over long distances. He wrote a celebrated poem (1530) entitled "Syphilis," and from this title the disease takes its name.

[432] Nenci (667 n. 143) provides reference to Fracastorius, *De sympathia et antipathia*, in his *Opera omnia*, cap. 7: *De sympathiis et antipathiis mistorum et attractione similium*, 85b, where Fracastorius states that he saw silver attract silver, and "quod valde mirati fuimus, magnetem vidimus argentum trahere."

[433] Just as a horseshoe magnet retains its power best when a "keeper" of iron normally lies across its poles. Cardano presumably reckons that the filings will keep the magnet "fed." But Scaliger (*Exercitatio* 131 [446–55]) thought that they protected it from the air, and noted that the filings didn't diminish in quantity.

[434] "sensum"; Agricola concurs that garlic, onions, and diamond have this effect (*De natura fossilium*, 5. 251; trans. Bandy, 85). The sentence appears first in 1554.

portions of the stone sticking to the iron's surface attract the iron to themselves. But conversely also, a large chunk of iron attracts a modest portion of lodestone to itself, and all the more so if the iron has been touched by a lodestone and the lodestone has been touched by iron. The reason this occurs it that the lodestone longs for iron as food; since the lodestone cannot attract the iron to itself, it is carried towards the iron, contrariwise. This stone has two parts placed opposite each other—one that lies towards the Equator, the other that lies towards the north. When it is dug up, it retains the same power, in the way that animals make their way back to their own natural base.[435] But since it is unable to move itself, because of its weight, when rubbed against a piece of iron it does move the piece (if the piece is placed in equilibrium), because the piece is free to move;[436] this occurs too because there is a natural principle that nothing moves itself. So since there are two parts of the stone, iron that is touched from the north directs that point towards the north; but if it touches the south, it is pushed towards the south, not the north. It is then not true that in our stones one can see more clearly than daylight that a magnet always directs iron to the north, since that part of it is significant in individual lumps, the part that directs iron to the south just as much as the well-known part does to the north. &495 The result is that people have been slow to notice its powers. But the parts are not directed precisely to the north or south, but individual parts are directed towards a point five degrees of heaven away.

The result is that in the case of sundials[437] the line on which the iron should come to rest in a compass is not the same as the meridian line,[438] where the shadows indicate hours; the line of the compass, if the sundial is perfect, deviates a little to the east of the meridian line.[439]

[475]Sundials[440] have recently been invented which display the hours as well as the meridian line without a compass; as they always show the same hour above,

[435] "situs."

[436] "ob facilitatem."

[437] "horologia." But the same word is used for instance at 27 (1560) in Book I to indicate a clock, spring-driven in that instance.

[438] "non eadem sit linea super quam ferrum quiescere debet in pyxide, et meridie [*sic*] ubi umbrae significant horas"—while the sense appears clear, it is not so clear why "meridie" is not "meridies," meaning the north-south line on a sundial, on which the shadow falls at midday, or (as it is in the 1550 ed.) "meridiei," to mean "(the line of) the meridian." Nenci's note here draws attention to the declination of magnetic north from true north, "observed and described for the first time by Colombo," which describes the discrepancy mentioned here by Cardano.

[439] This was true then at Rome; in March 1544 the deviation at Rome was 6° East (Georgius Hartmann, item dated from Nuremberg on 4 March 1544 in Hellmann, *Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus*, No. 9, 1899). The declination may have been known to Venetian sailors even before Colombo's voyage.

[440] The following two sentences first appear in 1560.

in front, and from the sides, and on a different basis, they must always have been set up so that the midline of the sundial was established on the meridian.[441] It is certainly a remarkable German invention. But there is no other explanation for the lodestone's deviating from the east to the right, except the position of the stone. The stone receives its powers from that direction, since it looks towards the rising of the star in the tail of the Lesser Bear which is five degrees to the east of the universe's pole. But from the opposite point of view, it is not from the southern stars but from the same Bear's tail or from its rise that the part of the lodestone that looks to the south receives its powers—which means that this stone evidently has contrary powers.

So it is no wonder that the suggestion[442] of the theamedes[443] has arisen, that it repels iron though it is a lodestone. &496 This is the position: one part of a lodestone propels iron to the north, the other to the south, as has been mentioned. But if the part that is aligned to the south is applied to a piece of iron that makes for the north, the inbuilt hostility[444] drives it away from itself with a greater vigour[445] than a piece of iron making for the south attracts it; and further, the part of the lodestone which looks to the north, when applied to the iron at that part where it touched the lodestone making for the south, repels it from itself. A piece of iron that is similar and making for the same part attracts powerfully to itself, but a piece of iron that has not encountered a lodestone does so only moderately. The reason is clearer than light itself: unlikes are repelled, likes are attracted. And so it is not that iron is driven away by any lodestone, but it is so in virtue of sharing in a contrary quality, or because the point on the other side has been touched by a similar lodestone; hence while that point is attracted, the other one is repelled. Consequently, if each point of an iron needle is touched by a northern part, both will be repelled by a southern part, as if it is pushing the whole iron needle.

There are people who assert that there is a part in that stone that propels iron to the east and another that does so contrariwise[446] to the west. I cannot offer anything certain on this. But on a basis like that on which iron is either attracted or repelled by a lodestone, another piece of iron is either attracted or repelled by iron to which a lodestone has stuck on contact. What I say is: when the point of a piece of iron has been wiped over by the southern part of a lodestone, then

441 The Latin (present in 1560 only) runs: ". . . cum eandem semper horam referant, et diversa ratione, fieri non potest, ut alter idem contingat, quam cum semper meridiei lineam media horologii fuerit constituta." I cannot make out the syntax nor translate except by guesswork.

442 "suspicio."

443 See n. 423 above.

444 "inimicitia."

445 "impetus."

446 "rursus."

when the iron is kept still, it propels another point away from itself—a point which has been placed in equilibrium and has touched the north part of a lodestone. And on the same basis, fragments of lodestone are attracted by a lodestone, since the lodestone or its fragments have &497 absorbed the powers of iron. And so lodestone does not attract lodestone, but iron sticking to a lodestone does it unperceived.[447]

Over and above these many notable phenomena[448] is this one, that a lodestone placed under a panel rapidly rotates a piece of iron placed in equilibrium on top of the panel, although the panel is in between—and those present are rather astonished. So a wooden basin full of water is put on the panel, a little boat is placed in it, assembled with very thin pieces of wood[449] without any iron, just with glue; on its prow a pretty little woman bends to row the little boat with an oar, so that her oar is moved by the boat's motion, and with it the figure of the woman; under the woman's rear foot, a little key with a broad head, and its wider part (called its cap),[450] protruding from the panel, is fastened in such a way that it is concealed below the prow and does not touch the water. The final touch is that a piece of an excellent lodestone is mounted in the head of a wooden rod of fir or cherry wood, on which the stone itself rotates when positioned under the tablet—and thus, with the lodestone placed under the head of the key, the ship will be drawn along wherever you like by the lodestone's motion, and the figure will look to those who cannot see the rod (as it were) alive[451]—and to turn and pull the boat wherever you want, like someone listening[452] and rowing. Matter itself, then, does not pass across, but something resembling spirit; the panel would obstruct the movement, since bodies cannot interpenetrate each other.

Through a similar scheme[453] a demon will give replies. A little statue of a crowned man is made out of brass,[454] in golden clothing, with horns on the head, with a black face and hands and feet, and the &498 hands and feet of a griffin.[455] In the right hand of this figure let a sceptre be placed, of zealously gilded iron and endowed with the powers of a lodestone. Let this figure be seated on a throne

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447 "occulte."

448 "dotes."

449 "tabellis."

450 "pileus."

451 "animata"—more precisely, provided with a soul.

452 To your commands, evidently.

453 "ratione." This paragraph first appears in 1554.

454 "orichalcum" or "aurichalcum": on this see 430 (1560) in Book VI, and n. to Book II at 106 (1560).

455 This fabulous bird is mentioned by Vergil (*Ecl.* 8. 27) as mating with mares, and by Pliny as having ears and a terrible hooked beak (*Nat. Hist.* 19. 36) and as digging up gold in Scythia (*Nat. Hist.* 30. 66). See A. Mayor, *The First Fossil Hunters* (Princeton: Princeton University Press, 2000), 15–53 for the basis of the griffin legend.

of glowing or blue brass. Let glass in the form of a column be placed around the whole contrivance, such as I have at times had in my hands, in solid form, or if you prefer, empty, and let the glass be linked only to the throne. Then let the device be suspended by a thin vertical thread, so that it can be rotated at will. Next, let the figure be questioned by means of a wand[456] moved in various directions by a piece of lodestone covertly placed on the tip of a slender wand. Beautiful rods, both unknown and known, and symbols as well as figures are added. A lodestone can also be hidden in a golden ring. We will put a statue of very light material on an altar, following the same pattern, and on the statue a piece of iron permeated by lodestone, the lodestone to be placed on a part of a wall, so that when it responds to the iron,[457] the figure's face turns towards a sacrifice. It is likely that such techniques were used to enable ancient priests to dupe ignorant folk, when people were still quite unsophisticated.[458]

Next after the rust-coloured lodestone comes the shiny-white one, and "creagus,"[459] as if drawing out flesh ; experience shows that it adheres with clumsy lips,[460] and is marked with some veins—it is rare, yet still found nowadays, since nature did not wish anything to be concealed from us. It is perhaps dragged dry from a wet place, and sticks with its lips, in the same way that straws usually stick to amber.

Similar to this evidently is another lodestone, of which I have the following &499 experience: Laurentius Guascus Cherascius,[461] an empiric physician in the province of Turin, had brought it along recently, and kept promising that if it touched a stylus or needle, they could go completely through flesh without any pain. As one might expect, since we thought this absurd, he confirmed the state of affairs[462] by experiment on my companions. In time, so as to test such an incredible state of affairs, I rubbed a needle first on the lodestone and introduced[463] it into the skin of my upper arm.[464] At first I felt the slightest impression

456 "virga."

457 "ut cum ferrum illum respiciat"—translation conjectural.

458 "nondum hominibus adeo solertibus."

459 Nenci (673 n. 150) illustrates from Albertus Magnus a tradition of the existence of an item that attracts flesh; it looks like a creation from the Greek of κρέας, flesh, = Latin "caro" and ἄγω, to pull (etc.), = Latin "duco"; hence the immediately following phrase here, "quasi carnem ducens."

460 "labiis haeret levis," which is puzzling, because "levis," meaning either "light" or "smooth," cannot refer to the lips—it would read "levibus" if it did. I have translated "laevis," suggesting clumsiness in these "lips." Agricola (*De natura fossilium*, 5; trans. Bandy, 86) is totally dismissive of this tale.

461 Nenci (673 n. 151) reports no trace of this person.

462 "rem."

463 Reading "intuli" with 1550 and 1554, not the "inutili" of 1560.

464 "adiutorium brachium"; this phrase is not mentioned in *OLD* nor *L&S*, but Castelli says that "adiutorium" = humerus, or the part of the arm that has only a single bone,

of a prick; later, since it was making its way virtually straight through the whole muscle, I could feel the needle penetrating into the depths on its journey, but I felt no [476]pain whatever—and then I believed my friends, because I had tried it out on myself. I gave up bending the arm in all directions for a long time,[465] and felt no harm, and when the needle was taken out no blood emerged, nor was there any hole; sometimes a half-drop of slight gore flows out, but not blood, where the trace of the injury is detectable. The originator of this happening was not eager for the locations of nerves or veins to be noted, so that we could clearly grasp that there was power in the stone. The stone was smaller than a little bean, shiny-white, or rather boxwood-coloured,[466] marked with rust-coloured veins, quite gentle[467] and smooth, so that altogether it would amount to the weight of thirteen grains of wheat. The needle I had put against it seemed so gentle when rubbed that it no longer seemed to retain the nature of iron, although very hard as before. So on thinking things over, three ideas kept coming to me. &500 The first was that the needle did not go in, but had provided another, changing its appearance with ours,[468] one capable of retreating into itself, not a difficult trick—but against this was our feeling the needle making its way deep in—and when it was being taken out, a good deal of effort was needed. Secondly, since there is subcutaneous fat between the skin and the subcutaneous fascia,[469] if the needle is introduced through the fat between the fascia and the skin, its entry would be painless. But what could actually support this explanation is that he had bent[470] the needle a little at its extremity, either while rubbing it on the stone or while he pushed it into the muscle.[471]

But there are many reasons why this theory is unsatisfactory. The first is, that by our senses we were perceiving that penetration had reached right to the bone. Second, that the extremity that was protruding outside the flesh was forming almost a right angle, so that the mathematical relation would not permit it to take up a position almost parallel to the skin itself, while the needle was standing entirely straight except at its extremity, and had also been a little bent (not much) at the same place. An additional feature was that the needle was visible under

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which is confirmed by reference to Vesalius, (*De humani corporis fabrica*, Bk I, 168) who mentions "adiutorium brachii" as one of several terms for the humerus bone.

465 "Dimisi vero longo spacio flectens undique brachium"—the syntax is hardly classical.

466 "buxeus."

467 "lenis."

468 "Primum, ut non acus ingrederetur, sed permutata similitudine cum nostra aliam obtulisset."

469 "carnea membrana."

470 It is unclear at this point who is inserting the needle into whom; the words here run, "quod acum in summitate paululum inflexerat . . ."

471 "seu dum in musculum per vim immittit."

the skin close to the hole, and resembled the appearance of a black rod. If it had all stuck close to the skin, that black rod would almost have been parallel to the length of the needle. A final point: that curved shape[472] could hardly make its way in without damaging the skin or the fascia, especially at that time, because he was handing over this procedure to whomever he pleased.[473]

So I fell back on a third discovery, which boys often use: when they pinch the skin on an arm painlessly with their fingers, and perforate it with a needle, also the lower fleshy prominence of the ear, after rubbing it with their &501 fingers beforehand. Rubbing evidently achieves four advantages for pain relief: loose structure of the part, enabling the needle to slip past without pain; warmth, which prevents the pain being felt—hence all hot things are distress-relieving;[474] and since pain is aroused by rubbing in any way, it relieves the pain of the prick. It is actually on written record that when two pains occur in relation to the same part, the greater blots out the lesser.[475] But this is not the only possibility: the lesser may blot out the greater, when they have not been of the same kind. In summary:[476] rubbing expels the spirit from the part that is more sensitive (and it is a nerve), and thus that part can lose sensation.

But in the earlier trial, the skin itself was not being rubbed—indeed, it was keeping a little of the sensation of pain, and the needle did not stick on the surface, but passed through the muscle. What then? Explanation must be drawn from elsewhere. Experience shows that a needle smeared with tallow does not excite pain when it goes in, or not much; was there maybe a fatter power in that lodestone, or one so cold that it stopped all sensation and flow of blood? Or is it in all circumstances a property of that stone, as it is of the rust-coloured one, that as I said, iron is directed towards the parts adjoining the poles? Or perhaps there is opportunity for an incantation.[477] But who can tell how much profit there may be in this scheme? Or who can work it out? We deal with much here that looks small, yet if turned to human use, would produce great benefit, and generally disgraceful profit. Arms for defending the fatherland and for the killing of travellers by robbers are the same arms. &502 Would not anyone say that knowing this trick is worth more than owning a five-hundred-acre farm—even a thousand-

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472 "curvitas."

473 "tum praecipue, quod hanc operationem cuicunque libuisset demandabat."—it is unclear who/what is the subject of this clause.

474 "acopa"; this corresponds to the Greek word "ἄκοπον," what removes distress, which appears in the Hippocratic *Aphorism* 2. 48, and preparations under this name are treated extensively by Galen in his *De compositione medicamentorum per genera*, 7. 11—end; K. 13:1005–58.

475 Hippocrates, *Aphorismi*, 2. 46.

476 "denique."

477 The remainder of this paragraph together with the following one first appear in 1554.

acre one? This point is made recently at Milan by Alexander of Verona.[478] His slaves and his boys too had been wounded by iron manipulated by this trick,[479] and all the flesh of their chests had been pierced, and hips too, and they were terrified by the wound and failed to notice that they were in no pain (the wounds were inflicted not by a needle but by huge swords) because through the application of oil containing a little sarcocoll,[480] or frankincense, or aloes, or some other constituent to show that the oil was not a simple, they got instantly healed. As I said, they were healed by the nature of a trickily inflicted wound—and though the oil contributed nothing, nevertheless all the power of healing was attributed to it. So it was on sale for what that sham bidder[481] would value it at. It would be easy to convince even any cunning person who is unaware of these tricks and poisonings that it was by the oil that these people were so speedily cured.

He[482] used, in such a downward collapse of mortals, to provide other powers, such as powers of soothing, of fending off epilepsy, of killing worms, of terminating fevers, which used to be helped both by faith itself, and by chance, and by the medicaments applied; in fact most bitters and odorous items can bring many pains to an end, disperse wind,[483] assist concoction, kill worms, terminate slow fevers, and help epileptics—all these have their base for the most part in phlegmatic humour. And so in everyone's view this oil is medicinal. So much of it was being sold, and it was so much valued, that that trickster collected nearly &503 six gold pieces per day, besides being described as equivalent to any very celebrated physician for curing the sick. Clad in purple, on a noble Asturian steed,[484] with a numerous retinue, generating confidence in deceit, he used to tour lands that overflowed with profit. He could not have borne so much expense with less.[485] But that exceptional oil, when applied to other wounds in his absence, used to give away the deception, as being no better, or very little better, than pure olive oil; even pure oil, as we have explained elsewhere, is capable of healing fresh wounds, since as we have said before, it does not decay.

But enough has been said now about the method and the causes underlying the lodestone's aligning iron [477]to north or south. We can also leave some doubts to posterity. Now my account can return to the rust-coloured lodestone. It originates in Spain and in the island of "Ilva" which lies between "Cyrnus,"[486] or

[478] Not identified. Even Nenci (676), publishing from Milan, does not offer an identification.

[479] "hac arte praestigioso."

[480] See n. to Book II at 92 (1560).

[481] "licitator."

[482] Presumably Alexander of Verona.

[483] "flatus."

[484] "Asturco."

[485] "Neque minore potuisset tantum impensae ferre"—syntax unclear.

[486] A latinisation of its Greek name Κύρνος.

Corsica, and Italy (it is nowadays called Elba), and in a number of other regions. But we have mentioned the nearer ones, so that people who suppose that iron gets aligned because of the regions in which it arises are shown up as in obvious error, and the actual regions in which this lodestone arises do not relate to those districts which a piece of iron rubbed on a lodestone,[487] and there is not just one region which produces its lodestone. It also resembles iron in substance and weight, so that it can be called "male," so to speak. Further, in things that possess senses,[488] the male is moved towards the female—indeed, he is drawn along by his senses. In those that lack senses, the &504 [misprinted as 564 in 1560]female is drawn along by the male. So this is why iron is attracted and hurried along by a lodestone—yet, as I said, they are carried along mutually, the one towards the other.

But why is there no other metal that is attracted by any other stone? This is because no metal is as cold as iron is, and perhaps it is quite impossible for other metals to be attracted by other stones. They are famous for their powers: sarcophagus,[489] calamochus,[490] halcyonium,[491] pumice, emery, tripolis.[492] Sarcophagus, so to speak "eating flesh," is light, white, rather ashen, friable, and on its top surface something resembling a light flour is present, and yellow veins on its bottom and inside. The ancients used to make tombs of this, which could consume actual bodies (apart from the teeth) in forty days.[493]

On the same principle, quicklime is inserted into vaulted crypts, and water is poured over it; if corpses are buried in it, they are normally consumed, as they

[487] "comes from"?—the syntax is guesswork here.

[488] "sensu praedita."

[489] Limestone; σαρκόφαγος, "flesh-eater," because of its reputation for consuming corpses.

[490] On "calamochnus" see n. 417 above.

[491] A kind of floating sponge, believed to be the nest of the halcyon, a bird supposed to nest upon the sea. This tale is related for instance by Pliny (*Nat. Hist.* 32. 86); and Ovid (*Medicamina Faciei Femineae*, 78) describes using the nest as therapeutic for spots on the female face. Castelli, *Lexikon medicum*, notes that Dioscorides listed 5 kinds of the nest (Bk 5, c. 136).

[492] Castelli remarks tartly that this is τρίπολις, a vividly lemon-coloured earth, with no or only rare use in medicine. It can be used for polishing: see 506 (1560) in the present work.

[493] This is stated by Pliny (*Nat. Hist.* 36. 131), who says that the sarcophagus stone comes from Assos in the Troad in Asia Minor, and so can be known as "Assius lapis." And indeed Nenci cites Agricola (*De natura fossilium,* 10. 371–72) who equates it with "Assius lapis," a kind of limestone also mentioned by Celsus (5. 19. 19) and Dioscorides (*De materia medica* 5. 141), and asserts its ability—especially that of the efflorescence from it—to dispose of corpses.

are also by cadmia[494] mixed with earth—anything rarefied and dry and capable of burning consumes not only the flesh of the dead but even their bones without restraint—and not only of the dead, but even of the living.[495] From this is made a painless scarring agent, which easily perforates the skin within twenty-four hours. If the skin is healthy, it is applied on its own, surrounded with leather, but if there is a gory ooze,[496] as happens with suppurations, the place is washed with very acid vinegar. The medicament is made from soft soap and quicklime finely mixed, so that it passes over into the form of a soft ointment.

On the same principle, sarcophagus benefits the &505 pains of gout as well as anything else can, by thinning out the humours. But the stronger the vinegar, the more it removes both the pain and the power of feeling; these agents summon forth what is inside, which thins and dissolves, and therefore vigorously dries.

Calamochus[497] or adarces,[498] foam from reed, originates in moist and boggy places around reeds and firewood, and in dry places is quite like slightly salty soap, and in powers quite like sarcophagus. Its colour is that of the asius stone,[499] full of orifices, very hot and acid.[500]

Almost alike to this in powers and form is what is called halcyonium,[501] that is, sea foam—and it is plentiful, and so in wide use.[502] The name seems to have been drawn from a bird's nest, a point on which we will speak lower down. But

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494 This is zinc oxide, calamine—*not* cadmium. Castelli, *Lexikon medicum*, has detail on it, distinguishing a native form with two kinds: one is cobalt, the other is devoid of metal and is "lapis calaminaris"; the manufactured kinds are varied and confusing. Crosland (*Historical Studies in the Language of Chemistry*, 107, 121) points out that Agricola used "cadmia" in various senses, and finally in the 18th century Macquer advised that "cobalt" should be used for one of the substances that had confusingly gone under that name. See also n. to Book V at 383 (1560).

495 Nenci here cites Agricola, *De natura fossilium*, 7. 324 to very similar effect.

496 "sanies."

497 See n. 417 above.

498 More correctly, "adarca," from the Greek ἀδάρκη, means a salty deposit or efflorescence on reeds (*OLD*). Pliny says (*Nat. Hist.* 16. 167) that it is "a growth, found in marsh-reeds, only coming out of the outer skin just below the tuft," and that it is good for the teeth and resembles mustard.

499 See n. 493 above.

500 Nenci here cites Agricola's *De natura fossilium*, 4. 247, which contains closely similar material, and remarks on the multiplicity of names for the same thing in the technical literature of the time. Agricola equates adarce with calamochnus (on which see n. 417 above), says that it is closely related to halcyonium, and remarks that it is too hot and acid to be of use on its own in medicine, but mixed with other items it can be administered externally.

501 See n. 491 above.

502 The remainder of this paragraph first appears in 1554.

it is not just the nest's name, but we also call a worthless waste of the sea by this name, and to put it generally,[503] halcyonium is a homonym.[504]

It is agreed that pumice is a kind of softer stone, burnt by sulphurous fire, and wafted on the breezes. It is said to prevent must[505] from fermenting, and when taken in advance to prevent inebriation, but not without severe sacrifice.[506]

Emery[507] is among the kind of stones from oystershell;[508] used on a brass wheel, it grinds most gems, and it cleans the teeth by brushing. The Romans used to engrave gems with porous stone and fragments of obsidian. But if emery is not a porous stone, they must have been unacquainted with it. Emery is of rarefied parts, and of compact and solid substance,[509] sufficiently to polish and sharpen iron; and it contributes a sheen to it and to steel. The sheen arises from the abrasion of the surface till it is made &506 flat and compact. Hence some things shine, some do not. Everything hard shines, and if it is harder, it is compact as well.[510] And so precious stones shine more than metals, and metals more than woods. And among the stones diamond, being the hardest; among the metals gold, being the most compact; among the woods ebony, among the bones ivory, among the horns buffalo[511] horn, on the same principles,[512] and whichever of these is more compact and harder will shine more. Brightness is enhanced by polishing the surface and by coating with gold, because gold, however thin, is always very compact. Items that polish are all hard and flat; what is flat is thin, or made from thin things. Hence tripolis[513] polishes more finely than emery;

503 "ut in universum dicam."

504 That is, a word with the same sound and (often) the same spelling as another word, but with an unrelated meaning.

505 Unfermented, or barely fermented, grape-juice.

506 Nenci cites Agricola, *De natura fossilium,* 5. 272–73, who claims that Theophrastus relates that those in a drinking competition who take pumice (the Gk word is κίσηρις) are at risk unless they take on a great deal of drink at one draught—but this item is not in *Theophrastus on Stones*, and the Loeb editor of Pliny, who is Agricola's source here (*Nat. Hist.* 36. 154–56), states that it is not in the *Historia Plantarum* either.

507 "smiris."

508 "ostracosorum"; not in *OLD* nor *L&S*.

509 The combination of epithets here appears self-contradictory, but not to Cardano; for instance, "tenuior ac densior" appears at 488 (1650) in the present Book. The remainder of this paragraph first appeared in 1554.

510 "Nitent quaecunque dura, ac ut magis, et densa."

511 "buffalus," corresponding to the Greek word βούβαλος, was classically transliterated into Latin as "bubalus" (*OLD*).

512 "rationes."

513 See n. 492 above.

this rust-coloured lump is closer to crocus,[514] or if you prefer, is a delicate stone, not because of hardness, but because of the rarefaction of its substance. Many items among these look softer although actually hard. Some of the soft items are regarded as hard ones through the presence of tenacious glue, as flint is; others among the hard items are actually soft, as tripolis is.

Tartar is made from the sediment of wine, and has no peer for scouring; so it is dingy, and originates in hard places, and cleanses outgrowths of flesh and displays the living flesh.

Gypsum is a shiny-white earth, sticky, light, suitable for shaping products;[515] it closes ulcers, and its efflorescence is called "talc" by a number of people. Some wish talc to be a different stone from "specularis."[516] Whatever talc is, it is like glass, scaly and transparent and resembling "specularis." When taken as a drink, talc weighing as much as a hazelnut benefits intestinal &507 difficulty marvellously.

The crustaceus stone[517] appears to be of the same kind—black in colour, marked with golden veins, and tablets made of it are exported from Nuremberg. There are innumerable tablets, of striking shape. The reason for the diversity is the one that will be mentioned in relation to herbs and trees.

Trochites[518] is striped on its flat surface, and on the middle of that is a point from which the stripes are aligned. But the flat surface is surrounded by a slight rim.[519] When placed in vinegar it moves about of itself, like an astroites.[520] The entrochos is composed of many trochites stones, and its power corresponds to that of its constituent parts.

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514 Crosland (*Historical Studies in the Language of Chemistry*, 71) points out that in the fifteenth century "crocus" was a term applied to yellow pigments only, and in the following century Libavius used phrases such as *Crocus Martis* (ferric oxide).

515 "fingendis operibus."

516 "lapis specularis": a transparent stone, mainly forms of mica or gypsum, used for windows etc. (*OLD*). The translators of Agricola (90–93) describe it as selenite, "gypsum occurring in transparent crystals," and Agricola treats of it at some length in that passage.

517 "lapis crustaceus." Agricola (*De natura fossilium,* 7. 323, cited by Nenci here) is describing types of rock that can be split ("fissilis") into "crustae" or flakes, presumably comparable to the "tabulae" here, and which appear to resemble what we call "slates." Of these Agricola writes, "pulcherrimae atri coloris tabulae aureis venis distinctae ex Norimberga Lipsiam apportantur."—closely reproducing Cardano's words here.

518 Castelli says it is a stone like a wheel, and children bowl it along. Nenci cites Agricola (*De natura fossilium,* 5. 261; trans. Bandy, 97), where information similar to what Cardano gives appears, but in more detail. See n. 420 above.

519 "tympanum"; in *OLD* and *L&S* this word means a small drum or cylinder, or a solid circular wheel. Here it seems to mean a rim round the "planum."

520 See nn. 180 and 181 above, where the same point is made about astroites.

The pentacrinos[521] is a striped stone that resembles five lilies. The encrinos consists of five pentacrinos stones, and is a red stone growing out of a black one. Likewise belenites[522] is arrow-shaped, with a [478]lengthwise crack inside—it contains another stone, joined to it by a gold-coloured slickenside.[523] And since some of these can attract straws, it is believed without foundation that they are "lyncurii,"[524] because they come into existence where lynxes are far off.

The conchites[525] is like a snail shell, embellished with curved ridges[526] and a gold-coloured slickenside.[527] And there is another kind of conchites: a species of marble—the shiny-white soft one, in which the shells of shellfish are always likely to be found; long ago found only at the town of Megara, as Pausanias[528] witnesses. This is a sure indication that the district was previously washed over by the sea;[529] since seashells are long-lasting, they turn to stone in many places between stones and under the earth, retaining their &508 shape but with their substance altered. The reason why most of them are provided with gold- or silver-coloured slickensides[530] is that their matter is hardly without saltiness; salt is shiny, and they consist of a pure portion of salt. What is made from the shells consists of the salty portion; when it has been extracted, a slickenside is created by the huge coldness of the site, since the watery part is shiny. And being well

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521 The origin of Cardano's remark about this is evident from its Greek derivation: pente (πέντε) means five and krinon (κρίνον) means a lily. Nenci cites Agricola, *De natura fossilium*, 5. 262–63 here, and Agricola uses this word there.

522 Castelli notes that it is more properly spelled "belemnites," traditionally derived from βέλος, the Greek word for a missile, because it was seen as arrow-shaped, and was elsewhere called "lapis lyncis," and had various medicinal uses.

523 "aurea armatura"; the word "armatura" means "the bright shiny surface of fossil shells, either original nacre or replacing pyrite and marcasite" (Agricola, trans. Bandy, 226), and so can be translated as "slickenside," which means "a smooth, polished or striated rock surface produced by friction."

524 Lyncurium is a kind of amber, traditionally derived from λύγξ + οὐρέω, i.e. from the urinating of a lynx; this is a more plausible derivation than Cardano's here. Agricola (*De natura fossilium*, 5. 266–67, cited by Nenci) discusses the tale at length, distinguishing belemnite from lyncurium.

525 Nenci cites Agricola, *De natura fossilium*, 5. 265, where the wording is very similar.

526 "liris incurvis."

527 "armatura." See n. 523 above. The remainder of this paragraph first appeared in 1554.

528 1. 44. 6, cited by Nenci, where this account is set out in similar detail.

529 In 1835 the eminent geologist Charles Lyell drew attention to this conclusion of Cardano's, a prelude to later discoveries on the earth's evolution—but it was also advanced by Bernard Palissy (1509/10—1589/90), Andrea Cesalpino (1519–1603), Conrad Gesner (1515–65), and (later) Niels Stensen (1638–86); see Eckman, *Jerome Cardan*, 76.

530 See n. 523 above.

mixed with thin earth, the watery part is not removed. There are some of these that testify to[531] a wise nature that looks to a definite purpose,[532] and some testify to an eternal universe.

The ostracis[533] is like the oysters, and is dug out like "specularis."[534] Similarly, onychites[535] is not unlike perfumed fingernails in form. And ctenites is striped like a comb. Strombites[536] is whirled into the shape of a whelkshell, inclining to a sharp point.[537]

Porphyroides is of ashen colour, abounding with purple needles like a slickenside[538] abounding with nails.[539] Myites is like a muscle, with very thin ends but swollen in the middle. But rhombites is of two kinds: one consists of scales resembling a rhombus, which gives it the name, and it is shiny-white; the other has the shape of a compressed cylinder, but striped above and below, to the extent that the stripes reproduce the shape of a rhombus.

The pentagonus and hexagonus have an edge, and in the middle a level space like a dice-box,[540] in which there is a point from which rays run out to the extremities, as with the rays of the trochites.[541] The Hildesheim district of Saxony produces all these, and Georgius Agricola was told about them by Valerius

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531 ". . . sunt . . . argumenta . . . sagacis naturae."

532 "finis."

533 Possibly equivalent to "ostritis," a kind of stone mentioned by Pliny (*Nat. Hist.* 37. 177) as owing its name to its resemblance to an oyster shell; or else equivalent to "ostracias" in the same passage, also known as "ostracitis," which resembles earthenware; it is mentioned also at *Nat. Hist.* 34. 103, as all black and very dirty and good for wounds. Or it may be equivalent to "cadmia," which Castelli equates to "ostracitis."

534 See n. 516 above.

535 Pliny (*Nat. Hist.* 34. 103) mentions onychit*i*s, "almost blue outside, but inside like the spots of an onyx or layered quartz," evidently a form of zinc oxide (cadmia; see n. 494 above) (*OLD*).

536 Nenci cites here Agricola (*De natura fossilium,* 5), who says this resembles a whelkshell, and mentions also ctenites, my(i)tes, ostracis, porphyroides, and onychites. Most or all of these stone words are directly derived from the Greek, making their meaning fairly obvious: for instance, ὄνυξ = finger (or toe) nail; κτέις (gen. κτενός) = comb; στρόμβος = spiral snail shell. Similar derivations apply to some of those that follow later here.

537 I.e. like a spinning top.

538 See n. 523 above.

539 "clavis."

540 "fritillus"; but note that Nenci cites Agricola (*De natura fossilium,* 5. 264) here, and Agricola on the same stones refers not to a "planities ut fritillus" but to an "alveolus," "little recess," which is much more comprehensible, and offers further details on these stones.

541 See n. 420 above; it appears to possess radial stripes.

Cordus,[542] a man of great knowledge about &509 herbs, who while living at Rome to pursue his enthusiasm for diverse studies like the German he was, was cut off by a premature death—to the distress of all learned and good people.[543]

This same man[544] also reported other stones, of unique and marvellous form, such as the glossopetra like the tongue of a woodpecker,[545] found at Luneburg in alum mines, and the selenites[546] in the shape of a Moon being reborn into its horns—this one is covered in some cases with a gold-coloured slickenside[547] or in others with a silvery or diamond one, and is found at Mariaburg. Likewise in the Trier district[548] the hysterapetra[549] is found, which presents the shape of the female genitalia—it is black, and very hard. And near Salphelda in Thuringia, in a well twenty orgia[550] deep, a stone was dug up which perfectly reproduced the shape of the intact human chest, with the intervals between ribs, but it was slightly narrower than a human chest.

The same man reported stones notable for their colour. Amochrysus[551] is of a golden colour, and scaly, and a sand can be made from it of a golden colour, suitable for the drying of letters;[552] I have found that if it is kept in a fire for one whole day, the supply of sand is more bountiful, and better and prettier. It is

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542 Valerius Cordus (1515–1544), was a German physician and botanist, author of a famour pharmacopoeia and a herbal.

543 Nenci cites here Agricola, *De natura fossilium,* 5. 265 (trans. Bandy, 101), however Agricola does not reveal the significance of Cordus's nationality, which Cardano mentions here.

544 Cordus, evidently.

545 Pliny (*Nat. Hist.* 37. 164) refers to this stone as resembling the *human* tongue, not that of a woodpecker, and remarks that it falls from the sky during the waning of the moon, thus being indispensable to the moon-diviner. The woodpecker has indeed an exceptionally long tongue (40 mm in the case of the Great Spotted Woodpecker), with which it extracts insects from deep in trees.

546 Pliny (*Nat. Hist.* 37. 181) says that this "moonstone" is transparent and colourless with a honey-coloured sheen, and "reproduces, if the report is true, the very shape of the moon as it waxes or wanes from day to day. It is thought to occur in Arabia."

547 "Armatura"; see n. 523 above.

548 In western Germany, some 150 km west of Frankfurt.

549 Nenci cites Agricola, *De natura fossilium,* 5. 263, mentioning the finding of a stone like this at Trier, but not its name—which, being derived from the Greek ὕστερον, the womb, is not difficult to invent; *OLD* does not indicate that it was known in classical antiquity.

550 Agricola, cited by Nenci (545 n. 16) with just the same words, spells the word "orgya." The Greek word ὄργυια means "the length of the outstretched arms, about 6 feet or 1 fathom"; ὄργυια is in modern Greek a measure corresponding to two English yards, i.e. 1.83 metres.

551 On "ammochrysus" see n. 418 above.

552 I.e. the blotting of characters written in ink.

the same with the armatura[553]—this stone is scaly too, but of a silvery colour, suitable at any rate for the same use, if for no other. The hieracites[554] too imitates with its grooves[555] and its colour the feathers of a hawk or partridge. And pyraustus,[556] which is of a ruddy colour, is notable for its golden slickenside,[557] hollow, glittering; hence it kindles fire when exposed to the Sun, just like a concave mirror; he found this one too &510 in the Hildesheim district.

Furthermore, in connection with alabandicus,[558] it is enough to know that it reproduces various painted pictures. And we have spoken about onyx,[559] and the stones found in the Verona district;[560] even in marble, the figure of a royal head with a diadem sometimes appears; and these things occur, as I said, sometimes by chance and sometimes because of the stone's nature. And we spoke about the stones of a flaky nature,[561] which resist fire, and about flint, which is also water-resistant, and is melted by fire, and that mountain summits are shattered by winds and cold spells, with stone fragments toppling down.[562] What remain to deal with are the black stones that can split into slabs,[563] of which there is a large supply in Italy, virtually free.[564] They are soft, and white lines are marked on the pieces of this stone. Saliva on its own makes a blemish. But they do not keep it long even if you do not remove it. They would be of use for working things out[565] if they were not so easily broken. For this reason tablets have been developed of thin linen covered with gypsum, and on top of the gypsum with varnish[566] (this is what people call this sort of liquid), and they bend and do not break. They take writing ink, and hold on to it for a long time, and only give it

553 "Armatura"; see n. 523 above, which explains its translation as "slickenside" when it means a feature of any stone, but not here, when it means a specific stone..

554 ἱερακίτης—ἱέραξ means a hawk or falcon; Pliny (*Nat. Hist.* 37. 167) says that it "is entirely covered with feathery scales, black ones alternating with others resembling a kite's feathers." Paulus Aegineta (7. sect. 3) states that it stops blood loss from haemorrhoids, and Adams in his commentary (3: 227) regards its nature as impossible to determine, remarking that Aëtius described it as a darkish-green stone.

555 "striae."

556 Aristotle (*Hist. animalium*, 7 (8), 605b11; Loeb 11: 195) mentions a type of moth called pyraustes (πυραύστης), without explanation of the name, but not a stone; no stone of such a name is traced in antiquity.

557 "Armatura"; see n. 523 above.

558 See nn. 239 and 240 above.

559 See n. 8 above.

560 See this Book at 466–67 (1560) for a previous reference.

561 "crustacea"—see also n. 517 above.

562 The following ten sentences first appear in 1554.

563 "sectiles."

564 "precium nullum."

565 "meditationes."

566 "vernix" —a post-classical Latin word. See n. to Book II at 92 (1560).

up to a moist sponge. I believe this kind of tablet was known long ago, and was in use, judging from the jest of Augustus, that Ajax had lain on the sponge.[567] However, the use of wax and stylus is common for letters and for working things out; but permanent records used to be carved in bronze. But it is clear from the eulogy of Marcus Marcellus, that a practice known in antiquity is in use by some people, who as abacuses use tablets made of fig wood and bone ash.[568] &511 As has been abundantly demonstrated above, a soul must be residing in stones. And I wish there was no life in stones, for then nothing would stop the generating of a large gem out of the powder from many emeralds buried underground, with the addition of very clear humour.[569]

From what has been said, we can appreciate that stones grow in a double way: either that matter is continually being added through the veins, and the stone is being nourished as a human being is; or that there is a potentiality of a certain sort in existence, as happens in the generation of a chick from an egg, and a product of that sort comes into being in actuality; as the days pass, a whole chick is completed, and its parts take their starting point[570] in matter at the same time, at nearly their whole size—so that what is previously white turns red, and then congeals into nerves, bones, membranes, and the like. And the fact that they move downward in water does not entitle stones to be described as earthy—a very small portion of earth in the congealed moistness is enough for the downward course. Yet all the transparent[571] ones are of watery substance, or congealed by cold, so that they are [479]melted by fire. Flint is not transparent, because it is earthy; but it breaks up,[572] because cold has congealed it. But the opaque stones (most of them are like that), and those that turn into lime, have not been congealed by cold at all, and are not of watery substance either; or if in fact they have been congealed by cold, since they do look cold, they contain a lot

[567] Suetonius (*Divus Augustus*, 85. 2) tells how the Emperor Augustus began to write a tragedy, but got on badly and packed it up; when asked what Ajax was doing, he replied that Ajax had "fallen on his sponge."

[568] As Nenci points out (692 n. 188), in Plutarch's life of Marcellus (17. *6*, not 17. 8) there is reference to Archimedes writing geometric figures on ashes. "How when he was dragged by main force, as he often was, to the place for bathing and anointing his body, he would trace geometrical figures in the ashes, and draw lines with his finger in the oil with which his body was anointed . . ." But this is not what Cardano asserts here.

[569] This is a difficult statement to interpret, since at 441 (1650) above, for instance, Cardano insists that there is life in stones, and it appears obvious that such life would facilitate the *spontaneous* generating of gems. But the statement may refer to the *artificial* generating of large gems by human intervention; then, no doubt, the presence of life in the ingredients might prove an obstacle to such meddling.

[570] "initium."

[571] "pellucidus."

[572] This is probably the formation of flakes of flint.

of earth, but little water. So it is evident that crystal, being transparent and melting easily, consists of watery substance that is pure and congealed by cold.[573]

&512 All this rests upon an unambiguous basis. But there are some aspects demanding more subtle and searching[574] consideration, since they appear to amount to a miracle. For instance, the account of Pausanias, that there was a stone beside the fireplace[575] in the citadel of Megara which when hit by a pebble gave out the sound of a lyre struck by a plectrum. I know how many people will jeer at me for relaying tall stories (especially ancient tall stories) like Pliny; but our case is not that this did happen, though it is well attested; rather, we are certain that it could have happened, and could happen later. The issue for careful enquiry is rather, how this could happen. Whether it is the product of nature or of technical skill makes no difference. Let us then take an example from technical skill, this being better known to us and easier to manage. Since in fact lyres give out a sound because the wood is hollow, and full of cavities, and spongy, and broken up by bends many times over, this needs to be devised in a stone. For it to be like that, apart from cavities and hollowness, there has to have been metallic matter suited for a sound mixed into it. Among the metals, only brass[576] resounds, and does so a great deal (we have said that copper[577] is Cyprian brass).[578] The ancients used to fabricate the tale that Apollo had put down his lyre there.

But there is another kind of marvel that astonished the ancients a good deal. There used to be a stone at Olympia which used to frighten horses so much that they broke the chariots and threw off their riders, undeterred by the whips and threats of the charioteers; the name "Taraxippos" was given to the stone, as if to say, "Disturber and &513 frightener of horses."[579] There was no poison about it, certainly no technical intervention[580]—the stone was like that of itself, being a large one that showed red and bright as a flame does, with a reflection of the

573 The following three paragraphs first appear in 1554.

574 "obscurioris."

575 "focus" = ἑστία. Pausanias's tale (*Description of Greece*, 1. 42. 2–3) runs that when this hearth or fireplace at a tomb at Megara was being built, Apollo was lending a hand, and laid his lyre on this stone. Subsequently, if it was struck by a pebble, it resounded just as a lyre does when struck.

576 "aes."

577 "cuprum."

578 This is hard to translate, because "aes" appears to be a crude product, either of any metal (*L&S*) or of copper, and the Cyprian product was famous for its purity as copper.

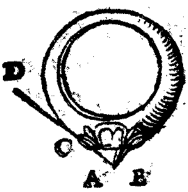
579 This appears to have had the shape of a round altar; Pausanias (*Description of Greece*, 6. 20. 15–19) accounts for it and its reputation as the terror of the racehorses in a variety of ways, and then mentions also that at Nemea, in the north of the Peloponnese, there was a rock above the race's turning point, red in colour, and the flash from it terrified the horses, though not as much as the "Taraxippos" at Olympia.

580 "ars nulla."

horses in it. So the horses either imagined there was a fire, or were misled by their own likeness, and were taking to flight; horses are particularly terrified of fire.

I recall what happened to me nearly three years ago now. I was at Genoa, and supping with the distinguished man Francisco Duarte, the Emperor's Quaestor.[581] After supper, very heavy rain fell. I was laden down with a cap, leggings, and a "gabinium."[582] Francisco, being a marvellously kind man, gave me well-bred horses; we climb up; Luigi Ferrari[583] was with me. While we made our way along a road, men carrying torches approached us; the wind was blowing from that direction, and carrying sparks in front of us, though at some distance. The horses were so frightened that we were in great danger, so much so that they could hardly be held in by the servants with us, even by pulling on the bits to prevent the horses from rearing. The track was narrow, with a paving of bricks sloping into a sort of arch, so that if they had been on end,[584] it would have been all over with us, especially as neither our escorts nor the horses could stand without slipping, because of the rain. And since we have mentioned this elsewhere, it would suffice here to have given a warning that horses are greatly frightened by fires, which means that Taraxippus did not put them to flight because of some miracle, but for a definite reason.

But to close by my setting a limit to the account of all the metallics, it is worth explaining how &514 genuine gems are distinguished from fake ones while they are partly hidden in rings. Hieronymus Guerinus from Oculi, the jeweller, (whom I mentioned above)[585] was the first to point this out to our eyes, and we contributed an explanation. Turn over the ring and examine the angles



and sides, and they will appear of a more dilute colour; suppose the colour is at C, the eye is at D, the angles are A and B—it is clear that D will not see A with the colour C, because the line DC falls below the point A. Again, if the ring is turned over, the result will be the same. But if the surface AB is placed upon a fingernail, the colour will not be visible in the angles,

[581] Francisco Duarte, a Spanish military man who flourished in Italy about 1543–1552 (*Enciclopedia Universal Illustrada*). He was also mentioned in Book VI, at 431 (1560).

[582] "gabanio": word not identified in Latin. But "gabbano" is Italian for a loose overcoat.

[583] Ludovicus Ferrarius. This man became a pupil ("Amanuensis") of Cardano's, though later his young life ended depressingly prematurely (for biography see *OO* 9: 568–9). He appears in *Dizionario Biografico* as Luigi Ferrari (1522–1565).

[584] "erecti."

[585] This is Hieronymus Guerinus, a Milanese from Oculi, who is also mentioned on 389 (1560) in Book V. Cardano's *De Vita Propria* (cap. 15, *De amicis atque patronis*, 12) also refers to him, and says that he taught Cardano many secrets.

but it will be more dilute; in a genuine gem, the potent rays get reflected[586] from the plane of the fingernail.

And there is another jewellers' street where they make a good deal of money, when very pretty assemblies of pearls are created out of shell.[587] This swindle succeeds so well because they are not recognised even by jewellers — the colour, brightness, substance, and weight are as they should be. There are even people who make these assemblies from two pieces, because of the thinness of the shell.

While I was writing this, a court case was going on about a pearl bought by a jeweller for 68 gold pieces, which had been made out of shell— the estimated price being 200 gold pieces. Jewellers used to have hopes of swindling the Germans and French, whom they suppose are short of ability and skill— they take them for barbarians, though it is we who are the real barbarians. Indeed, it is more barbarous to cheat than to be cheated. But this is enough about metallics; let us move on to the plants.

[586] "Refranguntur." The Latin word "refractio" was sometimes used in antiquity to mean "reflection," and seems to guide translation here; see n. to Book IV at 282 (1560).

[587] "est et alia non levis lucri seplasia, cum ex concha margaritarum pulcherrimae finguntur uniones." On "seplasia" see n. to Book V at 354 (1560).

[480] &515 Book VIII
On Plants[1]

Plants are nobler than the metallics, and in them a sort of image of sensation is glowing. Further, I regard it as plain enough that plants can hate and love, and possess limbs appropriate for their functions; the olive tree, the fig tree, and cabbages hate the vine, so much so that if planted close beside it they turn the wine flat. And the cucumber avoids the olive tree, and the vine is fond of the elm.[2] Similarly, a myrtle tree set beside a pomegranate tree makes it more fruitful, and itself grows more perfumed, and they both thrive and flourish to a remarkable extent.

There is a single general cause why some plants are harmful to others adjoining them: when the earth is flourishing in the Sun's heat and moisture, any shady tree must do damage to the others, and more if it has a multiply branching root; the vital moistness needed for the support of a nearby unaggressive plant is drained off by the branching root. Both the plants and the soil get chilled by the shadow, so that the very trees (or the grass lying in the shadow) visibly waste away for this reason. It follows that the walnut tree is at fault in both ways: it has close-packed leaves, and a branching root. And the fig tree has very large leaves. While I was writing this, I noticed that wheat sown beside a hedge in a field had become stunted, dry and scanty, and barely productive, although the hedge was low and sparse, and did not exclude the rising or setting Sun completely nor for long. So these are general considerations, and (as we said) there are others which are particular.

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[1] For an excellent general account of the history of botany, see Morton, *History of Botanical Science*. On the study of nature during the period including Cardano's lifetime, see Paula Findlen, "Courting Nature," in Jardine et al. eds., *Cultures of Natural History*, 57–76.

[2] For classical sentiments akin to these, see Vergil, *Georgics* 1. 2–3 and *Eclogues* 2.70; Ovid, *Amores* 2. 16. 41: "Ulmus amat vitem, vitis non deserit ulmum."

&516 There are four kinds of plants:[3] the trees, the bushes, the shrubs,[4] and the herbs.[5] A tree has a trunk that turns green recurrently or is always green, and reaches a notable size, as a pear tree does. A bush has a regular trunk[6] but does not grow to a defined size; examples are the rose and the myrtle. A shrub also has a regular trunk, but gets no bigger than a herb; an example is the "bruscus."[7] A herb is what lacks a stem—like the house-leek (that is, the "semperviva"),[8] and sage. Or else it changes its stem annually, like fennel. A fifth kind can be added intermediate between herb and bush—for instance, rue; sometimes it grows up into a tree, sometimes it stays as a herb.[9] And what happens to the stem is that it gets a very large head and grows huge, as it does in Pannonia.[10]

With skill, trees, herbs, and fruits grow a great deal, as do pomegranates and grapefruit,[11] also peaches. And there are some of the vegetables that are green even in winter, and with care turn into a bush. But none is more accomplished than rue; Josephus the Jew has left it on record that he saw one in Machaerus in Judaea which was as tall and large as any fig tree.[12] We ourselves have seen in the pleasure garden[13] of a Milan physician a rue plant which over many years had

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[3] Scaliger (*Exercitationes* 139–40 [465–75]) discusses at length various bases on which a classification of plants might rely.

[4] "suffrutices." Indeed this word is not classical and does not appear in *L&S*; Scaliger (*Exercitatio* 139 [464]) credits it to the "magnus vir Gaza." On Theodore Gaza see n. to Book II at 80 (1560). In his translation of *De historia plantarum* (34), the title of II. 11 runs: "Quomodo suffrutices herbae iterumque arbores nascuntur," and the Introduction remarks on how he fashioned new Latin words to translate those in his native Greek which lacked equivalents: "Adhaec suae linguae imitatione aptissimè fictis aliquando uocibus non infeliciter auxisse creditur linguam Latinam, alioqui inopem."

[5] Pseudo-Aristotle, *De plantis*, 1. 4, 819a42–b11; Loeb 169. Morton (*History of Botanical Science*, 50) writes that "the matter seems to have been derived from imperfectly understood scraps from Theophrastus and Aristotle, but it is a terrible farrago."

[6] "cuius truncus manet."

[7] This is the medieval Latin name for "butcher's broom," a shrub whose bristly leaf-like twigs serve as bristles for sweeping brooms. It is also the origin of the French (and adopted English) word "brusque."

[8] The word for "house leek" is "aizoum" (ἀείζωον) which is Greek for "lives for ever," "semperviva" being the Latin equivalent.

[9] The material from here to [A] at 521 (1560) appeared first in 1554.

[10] A pair of Roman provinces lying along the south bank of the Danube between approximately the modern Vienna and Belgrade.

[11] "citonia," possibly misprint for "citronia," but this is a guess; DuCange has citro = malum citreum, in late authors.

[12] See Josephus, *Jewish War*, 7. 178 (Loeb 3: 557).

[13] From about the end of the 13th century there were walled gardens in Italy, and works of art depict some in the 15th century. Boccaccio's *Decameron* (written before 1368) describes in its "First Day" an attractive one, and there were some probably familiar to Cardano at Milan, for instance in the Castello there; see R.S. Nichols, *Italian Pleasure*

converted to a bush. So it is clear that plants do not differ in kind[14] because of their size or vigour. Nor because of their leaves keeping the same size, or because one has permanent leaves and another deciduous leaves, or because the colour of the flower is not uniform, or because one is sterile and another bears fruit.

So the &517 distinction between plants is to be drawn from four points, of which the main one is its faculty or power—powers proceed from the form, which is what distinguishes the actual kinds. It is actually much less possible for a willow to turn into a chaste tree[15] than for a donkey to turn into an ox, even though a willow and a chaste tree are similar in fronds and bark. In fact the chaste tree is hot, and is dry in the third rank. The evidence is firstly that it disperses flatus, and that it comes into flower first of the trees—while the willow is moist and cold, and flowers late, and generates flatus. In addition, their perfumes gives rise to temperateness. Hence plants of the same species, even if one grows in India and the other in Scythia, must share in the same main powers. So it is absurd to believe that diverse and contrary powers reside in the same plants, or the same powers in different plants, and that the basis for plants and animals is not the same.

A second point of distinction is from odour, and a third from taste; the fourth, which is in fact the main one, derives from the shape of leaves, flowers, fruits, stalk, bark, roots—indeed, the whole plant. So far as size is concerned, what tree is actually taller than a cherry tree? But there are some of them, called the Macedonian ones, which are no taller than a palm. And so that debate comes to an end which once went on about bugloss and borage[16]—since they are virtually equal in form, powers, odour, and taste, evidently they should be placed in the same species. The fact is that since we seek names for them in the light of their powers, to a medical eye they clearly ought to be entitled to the same name, being endowed with the same powers. Not to a &518 herbalist, who reckons according to the shape, which a medical person does not. But where these two criteria agree, there must be others available. Hence the actual nature of things needs enquiry, rather than the words of Dioscorides;[17] though he was a notable recognizer of medicaments, and very diligent in dealing with them and very clear in explaining them, he was still an empiric in the type of his teaching, but a soldier in his discipline, and a man whose writings passed to posterity the worse for many blemishes. This is the source of their many disagreements, so that the inconsistency is now embarrassing. Medicaments are therefore to be sought not

Gardens (London: Williams and Norgate, 1929), 73, and Morton mentions how gardens "became the fashion and pride of Renaissance princes and wealthy families" (*History of Botanical Science*, 119).

14 "specie."

15 "vitex"; "chaste tree" or "monk's pepper," *Vitex agnus-castus* (*OLD*).

16 The borage, absent in 1550, was added in 1560.

17 See n. to Book II at 240 (1560).

by their names or their size or colour or fertility or for features that alter with the diversity of regions, but from their powers and shape, odour and taste. [481] Those that agree in these features are to be reckoned of the same species, and those that disagree, of different species. "The same in species" is said in many senses—some are the same in the final species, others again have many diverse distinctions. To lack one of these or to abound in the others is not determined by differences of species but of locations, since it is certain that a species does not vary more or vary less. Hence the ash tree and the bird's tongue, which some people call the fraxinella,[18] and dittany,[19] which we use—not the old dittany of Dioscorides, nor Vergil's dittany either; of it Vergil wrote,

> His mother[20] plucked dittany from Cretan Ida, a stalk with juicy leaves and decked with a purple flower.[21]

But as I said, &519 I have no doubt that our dittany is of the same species—indeed, its powers and form are the same. But the ash is a tree, the fraxinella a bush, dittany a herb, all of them plants of unlimited dryness, and hence unfriendly to snakes and quite deadly to worms.

Being more sturdy, the ash tree is supposed to repel snakes by its shade alone. And they all alleviate[22] diseases markedly for this reason. Hence the tale that Sancho the King of Spain,[23] being too fat to ride a horse or comfortably turn his hand round, felt weary of life, and summoned a notable physician from a king of Africa. He was cured with the seed of a herb which I suppose was bird's tongue.[24] However, either because poison had been added, or his bodily disposition had been changed from the contrary one, he soon passed away. And so there is agreement that these kinds of vegetation alleviate disease beyond measure,

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[18] "Bird's tongue" translates literally Cardano's "lingua avis." Identification is insecure; the phrase is not found in *OLD* or *L&S*, but Castelli mentions this as "semen fraxini," ash tree seed, and the tree's seeds, its "keys," are of a characteristic shape. The link to the herb dittany, also mentioned here, is commemorated in dittany's present-day official name: *Dictamnus fraxinella*, in which "fraxinella" is the diminutive of the Latin word "fraxinus," an ash tree. On dittany see also nn. 19 and 86 .

[19] "diptamum" here, but the reading "dictamnum" is now unquestioned in Vergil's text, a borrowing of the Greek word for dittany (see Durling, *Dictionary of Medical Terms in Galen*, and as Latin in *L&S*). The word also appeared in Book II, 344 (1560).

[20] Venus.

[21] Vergil, *Aeneid* 12. 412–414.

[22] "Extenuant"; the word is used by Celsus and Pliny in this sense.

[23] Sancho I, "the Fat," King of Leon in Spain 956–967. *Enciclopedia Universal Ilustrada* (53: 1244) reports that he was too fat to wield his arms or ride his horse, was nicknamed El Craso or El Gordo ("Fatty"), went to Cordoba to consult Arab doctors, and benefited greatly.

[24] On bird's tongue ("lingua avis" here), see n. 18 above.

since they remove spleen; indeed, they vigorously dissipate whatever they have alleviated. And this deserves its title as the best of medications for the obese.

But you will say: "Is it not the district that is the cause of smallness in these, since all these kinds are found in the same district?" But it does not occur because of the district alone, since plants of Macedonian cherries originated first in that district; moved from there, they keep the same smallness. The same happens with species of ash tree, and savin[25] and cypress and wormwood.[26]

Trees are also slimmed through nutrition, as dogs are, which we change from large dogs to normal ones by reducing nutrition, and their offspring into small dogs, and theirs to &520 very small ones. Women are well aware of this. The same applies to plants, which we transplant from another location or district, or wild and slender ones in mountains and a dry soil, as if they were trees or herbs of a new kind. But you will say: is not everything that agrees in form, powers, scent, and taste of the same species? Yes, the willow and the chaste tree have extremely similar leaves, trunk, and bark; what is more, both have a heavy scent, both are bitter, both unfruitful, both of them render men effeminate and sterile. But the chaste tree does this through being hot and dry, the willow through being moist and cold. The bitter taste and heavy scent are not alike, but differ in their basis in the two. The willow also sheds a tear, though a solid one, and hairy seeds[27] after it has flowered; the chaste tree does neither of these at all. A hairy seed originates in rotting moisture, or through rarefaction, as in thistles;[28] or through cold, as in the sow thistle and the willow. This generally predicts the winds and the weather, from the direction along which it flies through the air. The hairy seed is also harmful to the lung and the breath.[29]

But I return to the distinctions of plants: as I said, they are not to be derived from the colour of the flowers, but from other causes—nature has had a marvellous game with the colours of flowers. They are matt white, as are those of the gourd and lily, and of many trees such as the pear, the quince, the ash. Or reddish, like the amaranth's. Or scarlet, like the pomegranate's, and the poppy's that grows in crops and walled enclosures (it is called a poppy, though not really one). The iris bears blue ones, the crocus crocus-yellow ones, and the herb called calendula, &521 which flowers even in extreme cold—hence the name it has taken because it flowers on individual first days of a month.[30] The celandine has a golden flower, the mallow a mixed one, and the dittany we mentioned previously. Roses are the champion producers of diverse colours in their blooms; then come the violets, and the so-called cloves. Then jasmine, and hellebore—it

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[25] "sabina"; *Juniperus sabina.*

[26] "santonica"; "herba santonica" is probably a kind of *Artemisia* (*OLD*).

[27] "pappos."

[28] Reading "carduis" for the "cardis" of 1554 and 1560.

[29] "spiritus."

[30] "Calendae" or "Kalendae."

regularly bears both white and green and scarlet. But anyone will marvel at how nature has sported so variously in flowers without producing green or black flowers. About green ones there is a minor question: in fact the willow and vine have green flowers, but because of their resemblance to leaves we virtually disdain to call them flowers, although such excellent fruit follows upon the shortcoming of the flowers.

But there is a more profound point to consider about glossy black ones. Are any really black? And if there are, some doubt still persists, since they are extremely rare. Does a plentiful glow in the flowers reveal that glossy black is blue? Or, since glossy black must be situated in thick substance, is every flower derived from a very thin juice of its own plant? [A] But as the distinctions of all plants are virtually innumerable, it is not our purpose to cover them at length, as we did in the case of metallics; we have resolved only to deal with the more obscure points, not those that lie before our eyes. Therefore the account of plants and animals will be very brief. Some plants are town plants, some are wood plants, some grow in the sea, some in rivers, some on a river bank, some in marshes, some between rocks, some on ordinary soil, some (though few) among sand. And there are some, such as lichen, &522 in wells, some in shaded places, some in sunshine. Some[31] too are only from foreign parts, such as cloves, and cassia, and the bitter aloe.[32] The same is believed about the turpentine tree[33] and the mastic tree,[34] despite their being found in Italy. Furthermore, some are fruit-bearing, some sterile, some have no root, some no leaves, some no branches, some no flower. And some have hardly one of these—such as the truffles, the fungi, the maidenhair fern.[35] There are sweet-smelling ones, evil-smelling ones, and odour-free ones. Also those that are always in leaf and those that shed their leaves. Also some that are of sparse foliage, and some close-leaved, like the cypress. Others are wide-spreading, like the lotus[36] and the beech tree. And there are tall ones, and low ones; knotless ones, and knotted ones, like the bamboo. Some are dense, like the lignum vitae tree; some are empty inside, like the reed; some are [482]medium, like the elder tree. Some spring forth spontaneously, some are sown, and some through grafting or being forked in, like the willow and the vine; or through the seed of something else.[37] Some cling, like ivy;

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[31] This and the next sentence were first introduced in 1554.

[32] "agallochum."

[33] "terebinthus."

[34] "lentiscus."

[35] "tubera fungi polytrichum," without punctuation. This sentence is absent in 1554 and was introduced into 1560. However, 1554 contains a very similar short sentence a little further on, which is absent from 1560.

[36] This word "lotus" can classically indicate the nettle tree (*Celtis australis*, of the elm family) or various plants.

[37] "alieno semine."

some get implanted,[38] like mistletoe; some crawl about, like ground-ivy; some grow onto the earth, like moss and lichen. But moss also sticks to trees and to water surfaces. Some are healthy, some harmful: indeed, yew, walnut,[39] cabbage, savin, Spanish broom,[40] and in general everything that smells bad, so that silk-worms and rabbits — and still more, pigs—pollute the air. In some cases the sex is visible, as in oak[41] and holm-oak; in other cases not at all, as with olive trees and vines.[42] Some, like the palm, have a substance of their own. Some have fruits adherent to the branches, some in a pod,[43] some &523 enclosed in some other casing, like chestnuts. Some have them attached by a stalk, as cherries are. Some are found only in fixed districts, some everywhere. In fact the box tree, bramble, and bracken come up of themselves, and better, in a cold climate and where the winter is fierce. I mean the bramble that bears bramble berries, thus they are evidence of a cold region — as wheat is of a temperate one; and strongly perfumed things, which the Greeks call "aromata," indicate a hot one. Strongly hot seeds cannot actually mature in cold air, since they are of very rarefied substance. And without the air's help, nature cannot sufficiently concoct, dry and thin out the substance of fruits. But it can do this in the case of roots.

To continue: the parts of plants are: root, trunk, branches, leaves, fruits, pedicles, umbels, berries,[44] seeds, flowers, down,[45] wood, bark, fibre,[46] membrane,

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[38] "innascuntur."

[39] 1550 and 1554, but not 1560, include here a statement that the shade of the fig tree does harm.

[40] "spartum"; also means esparto grass.

[41] "quercu, et robore" — I cannot distinguish between these trees here; *OLD* gives "common or pedunculate oak" for "quercus," and adds that "robur" normally means an oak in general (in classical times), without distinction; the present-day botanical name for the Pedunculate or English oak is "Quercus robur."

[42] It is remarkable that Cardano should refer to sexual reproduction in plants, when its recognition is normally credited to Nehemiah Grew, who published in 1682. Morton (*History of Botanical Science*, 38, 213) mentions that even Theophrastus was aware that date palms could be fertilised by shaking male flowers over the female tree, but otherwise the sexual nature of plant reproduction appears to have remained unrecognised till Grew. Note 328 below refers to a further mention of this matter by Cardano.

[43] "siliqua."

[44] "acini."

[45] "lanugo."

[46] "nervus." That this word means here what would now be called "fibre" is suggested by the leaf anatomy in Theophrastus, *Historia Plantarum*, transl. Gaza; there (1. 17. 27), leaves such as those of reeds and corn consist only of "nervus," but those of fig and vine consist of nervus, cortex, and caro — fibre, surface layer, and flesh. There is much further use of the word in the present Book VIII at 613–15 (1560).

vein, matrix or pith, moisture, gumdrop,[47] knot, and many others. Through these and other causes trees and herbs differ from each other.

There are then trees that are of more open structure: firstly, all those that are clad in permanent foliage, being hotter and drier, on the authority of Theophrastus,[48] such as the palm, olive, cedar, and myrtle. This criterion does not apply in herbs, since the house-leek is of thicker substance, yet holds on to its foliage in winter. But in both cases the wild ones are of more open structure than the cultivated[49] ones, and the perfumed ones than the heavy-smelling ones or the odourless ones.[50] Similarly if they originate in mountains—&524 hence physicians prefer all these. But why are the roots more often perfumed than the other portions, excepting only the flowers?—as in the sanamunda.[51] The reason is that in roots a better concoction is achieved. Everything that has its moisture well concocted smells good; this type is the most rarefied and the most compact. Hence almost all flowers smell good, since the moisture in them is very rarefied, and quite scanty, so it very easily gets concocted. But the same cause that enables very easy concoction makes it perish more easily; it persists in the roots and trunks, as in the aspalathus,[52] which we call santhalum. Indeed, the rarefied substance of concocted moisture sticks firmly to earthy substance.

And so it is believed that in some boys and young men, their breath sometimes smells pleasant for good reason,[53] but can smell bad in the elderly or the intemperate—the rarefied moisture in the boys and the moisture in the young men rendered moderate by their great heat are capable of good concoction. In old men of scanty heat and intemperate, the character of the moisture prevents the achieving of complete concoction. This is the basis on which people say that long ago Alexander's breath was pleasant, because he had a rather dry body and a very high colour;[54] hence his corpse stayed free of foul odour for many days amid

[47] "lacrima."

[48] See n. to Book II at 80 (1560). In his *Enquiry into Plants* (I. 9. 3) Theophrastus mentions these and many other trees as evergreen, but does not include the remark about hotness and dryness.

[49] "domestici."

[50] Scaliger (*Exercitatio* 141 [475–84]) contests the basis of Cardano's views on plant classification in great detail.

[51] *Thymelaea sanamunda* is a flower found in the south of France with yellow blooms and a reputation for healing powers.

[52] A thorny shrub; Pliny (*Nat. Hist.* 12. 110 and 24. 111) says it is scented, and used in ointments in Spain. There is more on this shrub at 545 (1560).

[53] "non frustra."

[54] Alexander the Great (356–323 B.C.); the report is recorded by Plutarch (*Life of Alexander*, 4. 2–3; Loeb 7: 233): "Moreover, that a very pleasant odour exhaled from his skin, and that there was a fragrance about his mouth and all his flesh, so that his garments were filled with it, this we have read in the *Memoirs* of Aristoxenus. Now the cause of this, perhaps, was the temperament of his body, which was a very warm and fiery one."

extreme heat— though I would not dispute that it was preserved by technique, or by the same power of poison that is thought to have carried him off.[55]

To return to the parts of plants that &525 individually correspond to animals and to the parts of animals: as Theophrastus considers, roots correspond to the stomach, but we compare them rather to the mouth, and the bottom of the stem and trunk to the stomach; leaves to hairs, bark to the hide and skin, wood to the bones, veins to veins, and the fibres[56] of trees and herbs to those that are really present in animals. The matrix in certain plants that cannot live without one is comparable to the viscera of animals; and in others such as the willow, where the life is in the bark, there is the bark rather than a matrix, indeed in willows it is to be regarded in the role of the fat of the matrix. Eggs are comparable to flowers, semen to seed, the extremities of animals to branches. The actual fruit recalls the menstrual blood, in which mostly the seed is included.

There[57] are also parts of parts worth considering, as those of the root; its middle is woody, from which mostly the plant germinates. For this reason it possesses greater powers. Hence if it is removed from garlic, what is left is not so tangy, it does not smell so bad, and it seems less assuredly juicy. The second part is the coat,[58] which is quite thin; the third is the actual pericarp; the fourth is the external coat which surrounds the pericarp. I am not calling it pericarp in the proper sense, since the word is used of what surrounds the seed in the fruit, and indeed the fruit too, but I mean what encloses the wood in the root in the seed's position.

Hence in making decoctions physicians go wrong in throwing away the woody part, since it is best of all; what puts forth the sprout is the only part to have powers, because it alone has been alive. Hence the woody part is either the only or the main part of medical value. It alone sprouts, &526 because it is alive, and does so at the part that is alive. In chicory and the like, some leaves also germinate from the bark, but the seed and flower do so mainly from the wood. Thus as leaves come from the stem, so does bark from the wood—both are really for protection. At the bottom the juice is converted into root, the middle nourishes the root, the top part of the root turns into sprout. So the top of the root is its

[55] On the suspicions of poisoning and on how Alexander's body was embalmed, and on the subsequent grandiose arrangements for its preservation see for instance Lane Fox, *Alexander the Great*, 477–78. Plutarch (*Life of Alexander*, 77. 3; Loeb 7: 437) merely reports that it stayed remarkably fresh. Shakespeare refers to the story (*Hamlet,* Act V. 1. 217–220: *Hamlet*: Dost thou think Alexander looked o' this fashion i' the earth? *Horatio*: E'en so. *Hamlet*: And smelt so? Pah!).

[56] Reading "nerui" with 1550 and 1554 for the "uerui" of 1560.

[57] The material of four paragraphs here appears first in the 1554 edition. It replaced a brief statement exploding the belief that odorous plants always produce odourless flowers, which appears later at 527 (1560) .

[58] "tunica."

best part, and the one more independent of the earth's nature. The position in the flowers is similar: the leaf of the flower is what is always shiny, and overall, since it consists of very rarefied substance. And the calix or little sheath[59] is what contains the flower; and the seed, for whose sake the flower is created, just like the seed of generation,[60] and the pedicle, in which all this is mounted.

So perhaps we should enquire why all [483]flowers have a calix? But the flower of Apollo[61] does not; it has no calix, and is yellow, with six leaves in it. At each twilight[62] it shuts, and at midday is wide open. Some people say that at midnight it is tightly constricted, so that as for the planets there are four changes in a little circle: twin ones at the twilights, midway ones and like each other, the rest contrary ones.[63] One stem, one flower, a bulbous root, leaves like those of an arum lily. We saw it at the place of Gulielmo Caulio, a French nobleman. But the reason why most flowers have a calix is that before they are completed, the rarefied substance of the flowers was being dispersed. Consequently Apollo's flower has to be of dense substance, and like a leaf. But it differs greatly from a leaf in colour (as I said) and in having seed in the middle. The flower is in fact for the sake of the fruit, and what is more, of the seed. But why of the seed? &527 The seed is evidently concocted from the earthy part, otherwise no generating power could exist in it or be preserved there. There has to be some more rarefied moistness in every earthy thing, for it to combine.[64] And the moistness, especially if all inside, impedes both the generating power and preservation. Since it is present in what is being concocted, and gets concocted faster because of the rarefaction of its substance, some flower will precede all fruits. So the seed is generated earlier than the flower, if in fact it is completed for the flower's sake, but more slowly. And it is beyond belief that perfumed plants always put forth odourless flowers—some smell at every part, like the nard, the citron,[65] in which the leaves, flowers, and particularly the fruits smell excellently, and the rest is not odourless either. There are a number of species of citron, five of them very notable. The first, the one properly called citron, is a very big fruit and often larger than a human

[59] Reading "vaginula" for the "vaginulae" of 1560.

[60] I.e. animal seed.

[61] The rose was conventionally the flower of Apollo, but the heliotrope or sunflower seems intended here.

[62] I.e. presumably night and morning.

[63] Perhaps: closing at evening twilight, tight closed at midnight, opening at dawn twilight, wide open at midday. But I cannot explain the remark about the planets, since before the development of the telescope about 1609, changes in a planet's appearance (such as the Moon displays) could hardly be visible. Alternatively, the reference may be astrological effects of planets at rising and setting, not based on astronomical observation.

[64] The syntax is obscure: "Omni autem terreo, ut coalescat humidi tenuioris aliquid inesse est."

[65] "medica malus"; the "medica" means "from Media," the ancient Middle Eastern country.

head, even in Italy. The second is called "arantium," a name derived either from a corruption of "aurantium," because the peel is of a golden colour, or from the town of Arantia in the region of Corinth near the Asopus river.[66] Third is the lemon, which has the most acid juice in this group, so acid that the teeth are numbed by contact with it. The fourth is the limuniate, of the first species from the citron, and crossed with the lemon by grafting; it has a very pleasant smell and taste. The fifth is the Adam's apple, because individual fruits preserve the mark of a bite on their skin.[67] That all these are of the same species is demonstrated &528 firstly by their parts, which in every case are the same in number: peel,[68] flesh, juice, coats, and seed. In all too the plant is spiny, vigorous with permanent foliage, all fragrant. In all, the fruit is golden, but in the citron the colour is more dilute because of its size, and in the lemon because of its coldness. They are transmitted by grafting one into another, and the wood into leaves, and the flowers are so alike that only the experienced can distinguish one from another in the absence of fruit. They all have the same powers, and the acid taste is common to all. For them all it is appropriate to keep the fruit a long time and ripen it later. Also, they are all spoilt by the same causes—coldness, no doubt. They are maintained all together everywhere, so long as heat is not lacking. Consequently these individual species are found doing the world much good, not only in Europe and Asia and Africa, but also in all of Ethiopia and India—no fruit is so widespread in the world and so plentiful. The unique name of citron tells us that there was once a single tree; neither orange nor lemon is a Latin word, and the Greeks have no alternatives to offer. So it is accepted that the different names were invented, not in antiquity, but shortly before us, to meet the diversity of regions and of horticultural skill, also because of taste. The Adam's apple is derived by grafting from the citron and the orange, with technique mimicking the bite, and is later propagated, as we will explain later. It appeared that a cheap fruit produced in plenty in memory of our first parent[69] could be sold for more. But whoever he was, he devised the procedure &529 badly, displaying in such an unsavoury fruit so much feminine self-indulgence.

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[66] Neither derivation is well-founded; the word is the ancestor of to-day's word "orange" for the fruit, and the descendant of an Arabic word "naranj" for it, which became distorted in transmission through the Romance languages, perhaps losing its initial letter through confusion with the indefinite article (*una, une*).

[67] It will become plain shortly that the grafting procedure for producing an "Adam's apple" from a citron and an orange is manipulated so as to create a fruit with the semblance of a bite mark upon it. Robert Appelbaum ("Eve's and Adam's 'Apple'," *Milton Quarterly* 36 [2002]: 221–39) reflects at length upon Eve's and Adam's apple, its horticulture, taste, and the flesh of the forbidden fruit in John Milton's poem *Paradise Lost* (finished about 1663), but does not mention this presumably Italian manoeuvre.

[68] "cortex."

[69] I.e. Adam.

But you will say: orange peel is very unpleasing, lemon peel is pleasant; lemon flesh is very thick, orange has almost none. But these distinctions were drawn from the districts; orange fruit is hotter and drier and more undomesticated, but the pomegranate is virtually a domestic plant, and the orange plant is wild. Both of them are propagated, and in the same ways.

The most perfumed of plants, so far as I know (the day keeps bringing novelties), are the bitter aloe or woody aloe, cinnamon, aspalathus, nard, silphium,[70] and crocus. Pepper and ginger, very hot though they are, have little smell. Trees are of more rarefied substance than herbs, but are also more compact; the passage of time assists the Sun's power, hence concocted things are made more rarefied and more compact; trees live a long time, herbs perish quickly. And such herbs as smell good cannot long retain the smell except in the roots, because of rarefaction; and those that do, such as nard, should be reckoned among the bushes rather than the herbs. However, siliquastrum,[71] or pepperwort[72] or western pepper[73] is of prominent rarefaction. It is a herb with a long and practically red stem, frequent knots, the leaves of a laurel, white flowers, a single whitish root, with fibrous hairs, oblong pods that are large and quite reddish, like a purple colour, with prominent brilliance so as to suggest something poisonous, and a yellowing seed inside, a soft one. It is so pungent as far to outdo pepper, so that it must stand in the final rank of heat, dryness and rarefaction. Also, the actual skin of the pod has a &530 pungent impact while the pod is unripe. So although it came into use and was imported from the island of Hispaniola[74] in the other hemisphere[75] to ours in 1493, it is not without poison. Plants in fact contain poison as a rule either by nature or by chance—but nature is more potent in these. Those that are lethal by nature are those with the heaviest odour or taste (unbearable, like the one we said this siliquastrum has)—or are those that emit a juice that is not green, like all the kinds of spurge.[76] But even the fig emits a corrosive milk, and so does the lettuce when it has aged into excessive [484]coldness. In[77] fact when a juice is altered to another colour from green, it has to be corrupted, either through excess coldness or dryness or decay. Coldness obstructs the operation of heat; but dryness prevents the conversion of what is being concocted.

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70 "laser."

71 *OLD* cites Pliny (*Nat. Hist.* 20. 174) who identifies this word "siliquastrum" with "piperitis," the word Cardano uses next here, so they can be regarded as synonyms for pepperwort.

72 "piperitis"—*Lepidium latifolium* (*OLD*).

73 "occidentale piper." "Indicum piper" in 1550 and 1554; this India evidently the West Indies.

74 On Hispaniola see n. to Book II at 127 (1560).

75 "orbis alterius."

76 "tithymalum."

77 The text here up to [B] on 531 (1560) was first introduced in 1554.

So dry things are burnt before and in preference to their concoction; but decay overthrows what has already been done. Through all this a shiny white colour is created in juices, and from them a saffron-yellow one, but not through coldness—just as a shiny black one is, but not through decay. Hence every colour in plants except the green one is evidence of a poisonous quality.

But why is all plant milk quite tenacious? Because it gets viscous whenever heat has acted more than it should on the thin moistness and the fat mixed with the earthy. And so stickiness develops from the roots of plants that give out milk; plant milk is, as I said, tenacious. The juice of the root of a milk-bearing plant is mixed with the sap of a larch tree, and &531 Greek pitch with a modicum of oil; and they are cooked together long enough for the produce not to split on pulling apart. This stands up to water, because it bars oil from having water stick to it or mingle with it. A glue is created in the root from the decayed milk, such as the milk in plants from a location in the juice (as in lettuce, and chicory, and—through the abundance of moistness—in the fig). The evidence is that where glue is created in a root, there worms are generated too. A number of plants generate from these, but especially the one that produces a shiny white flower,[78] and after the pod has blossomed forth. There are also plants that create other things in their roots—for instance, the coltsfoot produces a wool from which there is excellent eating. And others produce colours—nothing actually prevents many of these being generated underground, since no one is astonished at it happening above ground—earth is the parent of everything. All that is generated underground is related to the juices; these products turn up more clear in the sprout. Hence spurge gives out a white juice, as I mentioned, but the celandine a yellow one. [B] And some of them glow, like all the kinds of buttercup, and especially aconite, which is extremely deadly—its glow proceeds from excessive dryness. Plants happening to grow in metal mines or beside the lairs of serpents, and which have matured beside copper or iron attacked by rust, and in marshes, bogs, drains and tombs . . . fungi too beside olive trees . . . all kinds of nightshade smell nasty and heavy. I do not know whether to list "stramonium" as "thorn-apple,"[79] or among the species of nightshade; certainly the leaves smell of the juice of black poppy. And if its fruits are cooked and eaten, they provoke a &532 prompt and ludicrous insanity.[80] The herb has a many-branched root, rust-coloured, with a finger-like stem, and also much thicker,[81] roundish, with a wide leaf, darkish on the opposite side. The cultivated herb has a stem green

[78] Evidently a single flower, since the word is in the singular number in the Latin.

[79] "Thorn-apple" is its present-day name; Cardano uses the equivalent, "malum spinosum."

[80] They contain the alkaloids atropine, hyoscine, and hyoscyamine, which they share with deadly nightshade, and their effects include delirium, hallucinations, and ultimately death.

[81] Than a finger, presumably.

and yellowing, oblong, soft, thin like a vine; the flowers white, emerging from sheaths like a basket, with a sweet lily-like perfume. But no identification is more obvious than that of the fruits, which equal Armenian[82] ones in size and shape, but are green and spiky; inside they are full of seed of a rusty hue, and are the size of a vetch.[83] There are some too that produce powers by their very shape—such as viper's bugloss,[84] which resembles a snake's head, and also provides outstanding assistance against viper poisons. Also, before the flowers of monk's hood open, they display the likeness of a dead man's head, or rather of a skull. Its root is actually quite lethal. Is this the outcome of chance, or of some natural cause? Or did some better mind[85] bring it about? In animals the same thing is evident: dogs in fact know the grass which makes them vomit; and she-goats know the Cretan dittany, on Vergil's evidence:

> These grasses are not unknown to the goats, when the winged arrows got stuck in their back.[86]

Again, if when donkeys are troubled by black bile they eat spleenwort,[87] they end splenic swelling.[88] People say, too, that swallows recognise the celandine,[89] and experience its powers with restored eyesight. On the same basis goldfinches[90] recognise eyebright[91] and vipers recognise fennel in order to mend their vision. Goldfinches are &533 often seen actually rubbing their eyes with eyebright during the morning hours—there are many instances of this occurring. But to ascribe everything to providence is ludicrous, because most things happen by

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82 Instead of "Armeniaca" 1554 reads "chrysomela" and 1550 "chrysomila."

83 "eruum." The next twelve sentences were first introduced in the 1554 edition and are absent from the 1550 edition.

84 "echium."

85 That is, presumably God's mind.

86 *Aeneid* 12. 414–415. These lines immediately follow those cited above at 518 (1560). The arrows mentioned are ordinary arrows which have struck these goats, and Vergil acquired from Aristotle (*Hist. Anim.* 9. 6. 1; 612a4) the tale of goats obtaining relief from embedded arrows by swallowing dittany. Ficino remarks that "the Cretan dittany has the power both to resist poisonous things and to draw the spear-head from the wound" (Ficino, *Three Books on Life*, 301).

87 "asplenum."

88 "A decoction of its leaves is said to reduce the spleen, the leaves being also applied locally" (Pliny, *Nat. Hist.* 27. 34).

89 The Greek word for a swallow is "chelidon" and for a celandine is "chelidonia."

90 "cardueles."

91 *Euphrasia* though 1560 reads "eufragia."

chance—nothing is more absurd—it would not be providence. We will discuss elsewhere what happens through providence and what does not.[92]

[C][93]But let us set this aside and return to the odorous plants, and to those that are more for use than for discarding. Silphium,[94] to start with, and its flowers have so much charm that according to Arrian, the local inhabitants are compelled to keep their flock away, in case it gets dispersed.[95,96] It originates in the mountain Paropaniso, although the Macedonians used to boast that they have seen it in the Caucasus. It has a stem like fennel, the leaves of celery,[97] a wide seed, leaf-like, a black root. We have a similar juice named Belzoi,[98] but not the same; for besides not being thin or hot or pungent, it also grows from the top of a tree. Hence Lodovico de Varthema[99] gave the cause of the mistake. They say that the wood called aloe has a similar distinguishing feature, being far more odorous than what reaches us. There are actually three kinds of it: the best is called "colampat," so fragrant that when held in the hand it blunts every other odour; for this reason it is not imported to us. It actually originates in the island Taprobana, which in the present age is called Sumatra,[100] both by its inhabitants and by the Portuguese, where in addition to notable resources it also prevents extravagance, in case the more costly incense should be exported to us. [D] I believe this is what turns entirely into a drop of sap when set alight, wood though

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92 It is unclear where this happens. There is hardly any further reference to providence in *De Subtilitate.* Cardano wrote a short treatise (*OO* 5: 15–28) entitled *De providentia ex anni constitutione* (Maclean, *De libris propriis*, M143 [108]) but it is concerned only with forecasting about disease.

93 Substantial expansion and revision occurred in the successive editions here between [C] and [D] on 533 (1560). For details the original texts should be consulted, which are available on the Internet.

94 "laserwort," *Ferula tingitana.*

95 Arrian (*Anabasis*, 3. 28. 6) reports this; the inhabitants even fenced off the silphium-rich areas with hurdles.

96 In the 1554 edition there are remarks here about a congealed kind of this juice called Belzoi, locally in good supply and therefore cheap, and views attributed to de Varthema. They are revised in the 1560 edition by remarks just below in this translation. For a full view of the revisions of this passage both the 1550 and the 1554 editions should be consulted.

97 "apium."

98 This is a variant spelling of benzoin, "gum Benjamin," an aromatic and resinous juice of *Styrax benzoin*, a tree of Java and Sumatra, used in perfumes, "friar's balsam," incense, etc.

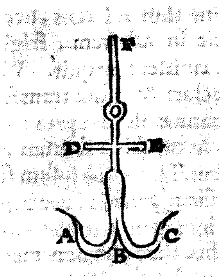
99 Vertomanus (Barthema or Vertomanus), a sixteenth-century Italian traveller from Bologna.

100 But in Ptolemy's map, the name Taprobana is linked to Ceylon (Sri Lanka), not to Sumatra. See J.L. Bergren and A. Jones, *Ptolemy's Geography* (Princeton: Princeton University Press, 2000), 20, 22.

it is. And &535 William Casanate of Besançon the physician[101] demonstrated this before our eyes.

The second kind is the one that sinks in water, like boxwood, and guaiacum,[102] though it is light, while oak floats, though devoid of air. Master Erasmus[103] recalled this observation,[104] and we have tried him out on it. Of this prime item there is a greater supply—but a lesser supply than there is of the cheapest. This is the one that neither dissolves into a drop of sap from fire, nor moves down into water; still, while it blazes, it smells marvellous. Though among the odorous things its odour is outstanding, the outcome is that from a medical point of view it is rightly admired among the [485]aromas. People have long sold wild olive[105] in the place of bitter aloe. Either because of the district's nature or because it is a plant of the other kind, this product of Rhodes actually recalls bitter aloe in colour, and does not appear entirely odourless—it smells pleasant, but not much. This does not seem difficult, because rare woods are better concocted by their own heat. And a good odour is the exhalation of well-concocted moistness.

But why do timbers not stay vertically upright in water, but lie flat and parallel to the water surface, yet when they are thrown down from high places, they pass down in the air with one or other end leading and vertical?[106] The reason is that it is normally released from one or other end, so that it cannot turn round, because of the short time and the impetus. But when it moves down sluggishly in water because of its thick composition, the remaining end of the wood makes for the bottom too, so that the whole of the wood stays in equilibrium in water. This is how ships are kept steady; an anchor ABC is tethered to the ship by F and flung into the sea, in such a way that at its lower end B it touches the bottom. &535 To prevent the bar DE, when pulled, lying fixed on top and perpendicular to the water surface, and the sea bottom (DE in fact lies perpendicular to the surface AC, in such a way that if it were at B, it



[101] This is Gulielmus Casanatus Besuntinus, physician to Archbishop Hamilton of St Andrews in Scotland; for the tale of how Cardano came to treat the Archbishop, see C.L. Dana, "The Story of a Great Consultation," *Annals of Medical History* 2 (1921): 122–35.

[102] "lignum sanctum." On guaiacum, see Robert S. Munger, "Guaiacum, the Holy Wood from the New World," *Journal of the History of Medicine and Allied Sciences* 4 (1949): 196–229.

[103] Erasmus (1466–1536), born in Holland, was the greatest classical and humanist scholar of the Northern Renaissance, and a major influence on Protestant thought. Reference here not traced.

[104] "experimentum."

[105] "oleastrum."

[106] "altero capite ac rectè."

would form a cross with hooks) then since AC lies perpendicular to the surface DE, and DE is parallel to the bottom of the sea, from the 14th proposition of the eleventh book of the *Elements* of Euclid, AC lying down perforce perpendicular on the bottom of the sea—it follows that A or C, one or other of the hooks, will be fixed to the sea bottom because of its gravity, and the ship will be held fast.[107] So if the beam DE were not present, on the theory set forth AC would fall always parallel to the sea bottom, and therefore could never get fixed or hold the ship fast. This is why anchors are also made with four hooks set cross-wise, but are less reliable than those that have two with a transverse beam—if they do stick, they are also much weaker.

But I return to the account of plants. Cinnamon is similar to the laurel tree—leaves like its leaves, trunk like its trunk, except that it is low,[108] and spreads out wide like a willow. And cinnamon berries are like laurel berries, but &536 smaller, and glossy white. One might therefore suppose that there is a single tree, but diverging simply because of the districts. The Indian heat, unlike Europe's, can perform an excellent concoction of the bark's moistness. Cinnamon bark is pulled off the branches and dried; the trunk is left intact, to prevent the tree dying. With the passage of one month after bark-stripping, the odour's charm is released. Some people say that cinnamon is like the pomegranate tree—it has many twigs,[109] and delights in dryness. Further,[110] an oil of effective and delicious smell drips from the berries as it does from laurel berries. I call "cinnamon" the product in common use—not the one sought by the ancients long ago. That one was of a very delicious and fragrant odour, and full of knots, and of a colour mingled from glossy white, blue and black. But nowadays it is rare, even at the Emperor's. Ours seems more worthy of the name of cassia. Because it, the ancient one, was like that, it had to be of very rarefied substance; there is in fact a fragrance, and it is itself the gift of subtlety.

The nutmeg[111] grows in the island of Banda,[112] just as cinnamon does in the other island called Ceylon[113]—both are Indian. Further, the tree is totally like the peach tree in its stem, branches and leaf, except that the tree is bigger, and the leaves a little more narrow. The actual nutmegs are surrounded by a sort of

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[107] I find it very difficult to follow the detail, but the general picture seems clear enough.

[108] The statement that the cinnamon's trunk is low is not present in 1550 and was introduced in 1554.

[109] "surculosus."

[110] The remainder of this paragraph first appears in 1554.

[111] "myristica nux."

[112] Banda corresponds approximately to Indonesia, and the cultivated nutmeg is still known as the Banda-nutmeg.

[113] Kerr (*General History and Collection of Voyages and Travels*, 7. 16) testifies to the cinnamon in Ceylon.

flower[114] and by another coat, just like walnuts. Further, the inner coating, which is even thinner and reticulated under the nut-like growth,[115] is generally called "Macer,"[116] and is itself of a pleasant odour, and we make frequent use of it. It is astringent, and does not do much heating.

&537 The[117] clove grows in the Molucca Islands, which are five small ones under the Equator. It also grows in the Gilo island,[118] which is a good deal larger than Sicily, and in another small island beyond Tidor, which is one of the five Moluccas. The Moluccas are Tarena, Tidor, Muttir, Macchia, Bacchia.[119] But what grows on the little island closest to the Moluccas is not genuine clove. The skin, wood, and leaves of clove are no less pungent than the fruit itself. It grows on hills, and the slopes of hills; and it is surrounded daily by a cloud which contributes much to their ripening. If this tree is removed elsewhere, it dries up, so that sufficient agreement exists that it is the noblest of the aromas, as it were "the ultimate of the incenses."[120] The plant has a stem like box, leaves a little more rounded than those of a laurel, and its trees are crowded enough to make a copse. From the top of the little branches grows a larger clove, which people call a nail,[121] but previously there is a flower in a wreath there very like the flowers of a Seville orange.[122] The point of the clove fruit rests on a stem, but at its wider part it diverges from the plant. It turns reddish initially, but soon darkens.

The Moluccas also export ginger, which grows everywhere, and also elsewhere in a number of places. It is therefore less valued, and also because it is a herb with roots resembling those of an iris, a plant I believe of the same kind—roots multiple and very large, so much so that some weigh twelve ounces. One is left behind for propagation.[123]

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114 "flore quodam."

115 "nucamentum": *OLD*, citing Pliny, *Nat. Hist.* 16. 49.

116 Castelli helpfully defines this term as the aromatic coat of a plant, and cites Galen, Dioscorides, and Matthioli in support, remarking that it is a botanical term, and Castelli does not wish to make an issue of it!

117 The following seven sentences, first introduced in 1554, are a considerable amplification of the acount in 1550, in which the clove's origin is named as "the island of Monoc."

118 The Gilolo island is on the Equator, south of the Philippines, east of the Moluccas and Celebes, north of Amboyna and Banda. It is in fact much of a size with Sicily.

119 Some of these names are clearly recognizable as those of present-day Molucca Islands in the eastern part of Indonesia: Ternate, Tidore, Makian.

120 "ut thymiamatum ultimam."

121 The Latin word "clavus" means both a nail and a (large) clove, and the visible resemblance between the two is obvious.

122 Syntax not clear: "corolla prius tamen in ea flos persimilis floribus citranguli."

123 1550 mentioned here that the stem resembles that of a middle-sized pear tree, and the leaves resemble grass.

Pepper is not much different from ivy, a low bush, and one that cannot exist on its own, but sticks to other trees, and people &538 think it is not linked by pedicles—it puts out more branches, two or three palms in length.[124] From the individual mallet-shoots[125] six bunches hang no larger than a palm, and quite like the grape bunches from which raisins[126] are usually made, but with closer and more tightly-packed granules, which are gathered in October and [486] November still green, and after three days' exposure to the Sun are turned black. But the tree's leaf is virtually very like the leaf of the plantain, which adheres linked to the fork with a quite short pedicle. However, at the part where it joins the pedicle, the leaf is rounded, but at the very tip is pointed, like a citron, and the leaves at the tip terminate. At the back of the leaf there are seven fibres,[127] as in the plantain, but those at the sides do not start from the one in the middle, but from the intervals, inclining from the bottom towards the top of the leaf; they enclose the middle, arranged obliquely, and not evenly, nor is there that thickness which is present in the leaf of the citron.

The tree of the long pepper[128] is much taller, and the leaves larger than those of the round one, but very similar.[129] It is sufficiently established that just as we explained that cinnamon tree is a species of of the laurel, so pepper is a species of ivy, perfected and improved by the district's climate; it is at Calicut[130] in India that it grows, and also in a field near the town. The evidence for what we said is that when this tree is transferred to our country, after a few propagations it changes into ivy.

I know this is inconsistent with Dioscorides; but the ancients wrote down what they heard; they deserve indulgence for being emboldened by necessity and the search for glory.[131] On the other hand, they spared neither labour nor &539 diligence nor money. A flower we have took its name from the clove fruit, through the attraction of its odour.[132] It is shiny white, another one reddish, another of the two colours mingled. It is a low herb, with the leaves of a leek, but narrower. It is cultivated with great care in pots, and looks as attractive as it smells.

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[124] 14.8- 22 cm; on the dimensions of a palm, see n. to Book XVII, at 1080 (1560).

[125] "malleoli."

[126] "passulae"; the word is not in *OLD* nor *L&S*, but since "passum" is raisin wine, the likely origin of this word is clear.

[127] "nervi."

[128] "longi piperis."

[129] This sentence was introduced in 1554.

[130] Calicut is on the west coast of India, some 350 km from its southern tip (Cape Comorin); it is not to be identified with Calcutta.

[131] 1554 in this sentence is rather less indulgent of those "ancients," remarking that they got away with their errors because the relevant plants were so far away.

[132] Pinks, carnations, and Sweet William; they are known as "caryophyllaceous" plants because their smell is reminiscent of that of a clove, "caryophyllon" or "garyophylum" (Cardano's spelling).

There is also the frankincense plant; the temples of one's head are often fumigated with a drop of this, because while it burns the smell is highly attractive. A fir tree (the little one) which the Sabaeans[133] have emits this drop of sap, because of the dry climate. Hence the poet Vergil:[134] "The gentle Sabaeans have their frankincense." The sort that runs out of itself is more potent, and what only runs out from wounds in the tree is weaker—a feature worth noting in all liquids. But with us, there is esteem for a single type of fir, which rises extremely straight amid the trees. Consequently it is preferred to all other woods for the patterns of statuary[135] and every other task of fabrication, so that what you can hardly (and not safely) achieve technically in the other woods, nature excellently facilitates for you in the trunk of this tree. It[136] grows to such a size that in Zofingen,[137] in the Swiss province of Berne, most exceed a hundred and thirty feet in height. The straight part, thick, always evenly so and knot-free, a hundred and ten feet. Hence they are worth carting a long way to Ianua (or Genoa, if you prefer) for making the masts of ships. In fact they are transported first along the Arola[138] river, then the Rhine, subsequently through the English sea, then the &540 Spanish sea, and finally the Mediterranean. We saw this while we were at Genoa, many of them of incredible height, straightness, evenness, and thickness, so that one had to marvel at Nature's effort. On Vergil's authority, it is born in the mountains: "The fir in the mountain heights."[139] The cause of them is primarily the plentiful supply of juice; nothing large can exist without matter. Next comes vital power;[140] growth requires time. There is also the minimally many-branched nature of the fibres making up the trunk of a tree, but it is simple, and knot-free, and evenly mixed with earthy stuff. The simplicity of the fibres comes about from the power of the particular species; St John's Wort is forked in every direction, and others likewise preserve the same plan in the multitude of their fibres.

But I return to the account of frankincense. As savin is the nearest to cypress, so is rosemary[141] to fir, because it is bushy from the kind[142] of the tree. Thus I have seen in the Apennines a herb—or rather, a shrub[143]—like rosemary, indeed from its kind, with narrower leaves, a pungent taste, which so closely reproduces the

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[133] A people of SW Arabia.

[134] "Mantuanus," the poet from Mantua, i.e., Vergil. And in his *Georgics* (1. 57) the phrase appears: "molles sua tura Sabaei."

[135] "plastices proplasmatis."

[136] The remainder of this paragraph first appears in 1554.

[137] About 50 km NE of Berne in Switzerland.

[138] The Aare, which runs from near Zofingen into the Rhine, in N. Switzerland..

[139] "abies in montibus altis"—Vergil, *Eclogues* 7. 66.

[140] "vivacitas."

[141] "libanotis."

[142] "genus."

[143] "suffrutex." But 1554 uses "arbustum" here.

odour and taste of frankincense that no doubt remains that frankincense must flow from no other kind of plant. So the frankincense tree, the fir, and rosemary are of the same kind, but differ through the quality of the regions and the vigour of nature. In Arabia, because of the soil's fertility frankincense comes out of a plant; in a colder climate the fir grows into a tree, and emits a less effective but more plentiful sap. Rosemary, recalling frankincense by its &541 name,[144] drier than a fir, does not grow up into a tree, and being colder than frankincense cannot emit a drop of sap.[145] But one can estimate their powers from these features and transfer their use, and wonder at the works of nature in them; almost the same principle in all kinds of trees and herbs. Frankincense [146] itself or a drop of sap is not of the same kind nor equal in all cases—the Ethiopian sort is so fragrant that ours does not deserve the name. But not all of it, only a particular species. The evidence is its scarcity, and its expense even among them.[147] Hence only their kings use it (who are called Negus in their mother tongue), for the fumigation involved in their religious rites. No wonder—there are diverse species of horses and of dogs, and there are some superior species of individuals, with the soil making some contribution. The cultivation of the trees has an effect, with some being between stones, and in sunny places, also the method of gathering the juice, or because it is entirely pure, or because it drips of itself, as occurs in the case of wines, where differences in the plan for gathering and extracting are so many and various, and so large, as to be beyond the belief of anyone without experience of them. Most juices are in fact ignited by fire, and those of them that are called arteriac[148] are the worst, such as liquorice.[149] The best juice is all that is translucent and firm[150]—because it is translucent, it is pure, and very little burnt up; because it is firm, it is rich in fatty moistness. Aloe is thus excellent, and the rest of the juices; then the drops of sap. But the position with incense is very different—its odour resides in dried moistness, and it should not be &542

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[144] It is not evident in what way the *names* might resemble each other. But Pliny (*Nat. Hist.* 19. 187) wrote of "libanotis" (the word for "rosemary" used by Cardano here) resembling "thus" (frankincense) in *odour.* If this is the explanation, here "odore" would have to be read instead of "nomine."

[145] "lachryma"—a teardrop, translated in this book as "a drop of sap."

[146] The remainder of this paragraph with the two subsequent paragraphs first appear in 1554.

[147] The Ethiopians, presumably.

[148] Galen (*De Compositione medicamentorum secundum loca,* 7. 1–2; K. 103: 1–61) wrote of these as medicaments useful for impairment of the voice and faults of the *aspera arteria,* i.e. trachea and bronchi (not the blood-carrying arteries). He also discusses them elsewhere, so that Adams (in his transl. of Paulus Aegineta 3. 28; translation 1: 473–74) fairly remarks that Galen "has treated of these diseases so fully that he may be said to have exhausted the subject."

[149] "liquiritiae seu glycyrrhizae."

[150] "consistit."

burnt up, as the flame has no odour, but the smoke does. Thus the dust has none; it is burnt up, and does not emit smoke. Hence all that is odorous should be thick, and those that are of thicker substance, like frankincense, are moderately ground down. A very fine dust has no smell, and in proportion as it is of thinner substance. But watery moistness obstructs [487]odours; so long as it is present, none occur; while it is being removed, what is fatty gets burnt up; fatty moistness is more readily consumed by fire than wateriness.[151] It is fatty moistness that gets burnt. As Vergil puts it: "Fires burn in fatty juice."[152] Therefore before the watery moistness is consumed, the fattiness is ignited, and thus the fragrance is released.

But I return to the sap of trees and herbs; their distinction[153] arises either from odour (as does that of asafoetida), or from colour (as does that of lacca,[154] which originates from a tree like the cherry in East India); or from the use, like that of the larch tree, which does a great deal for those with phthisis and leprosy. Hence a hot chamber[155] heated up with larch tree wood heals the latter, and contributes a good deal to the former, and so much so that water recovered by distillation also notably benefits both diseases. But a larch tree is better for these applications when it is not bent by rain or winds. The fir and larch and pine are of the same species. But the sap of the fir is more important, and that of the pine is worse, with the larch in the middle; in fact they agree in juice and form, and in almost all the accidents. This juice is as fatty as blood is in animals; hence it is more dilute in the more delicate plants, and darker in &543 old ones, but clear and fatty in mature ones. This is why any sap is hotter and moister that glitters, but colder when dilute, and if drier it is dark. It is mainly in the larch that a sort of agaric fungus bulges out, and though it is very light and white, it will be excellent both when least woody and when sweet after being bitter. Some things are

[151] Syntax obscure: "facilius enim absumitur igne pingue humidum aqueo."

[152] "In pingui fervent incendia succo"—The sentence does not appear in the now recognised works of Vergil, but is found at line 396 of the poem *Aetna*, a didactic poem of unknown authorship, though probably composed around Vergil's time, which seeks to explain the volcanic activity of Mount Etna. It is included in the *Appendix Vergiliana* of works at one time regarded as genuine works of Vergil, although doubts had arisen as early as the fourth century A.D. Hence Cardano so attributes it. A little earlier than Cardano, in 1495, Pietro Bembo at Padua published a poem with the same title, *De Aetna*, which drew on the earlier work and appears to accept its Vergilian authorship (Bembo, *Lyric Poetry and Etna*, xxi n. 9).

[153] "nobilitas."

[154] This word to *L&S* is "a plant otherwise unknown"; in Castelli it is a word about which physicians hold diverse opinions.

[155] "aestuarium"; DuCange (*Glossarium*, 1: 120) traces an instance in a MS dated 1318 where it means "hypocaustum," or a heated room, and the *Mittellateinisches Wörterbuch* (1: 334) notes the meanings "balneum, sudatorium." The word appears in Fernel, *De Abditis Rerum Causis*, ed. Forrester and Henry, 653, n. 266.

sweet after bitterness, such as the cubeb fruit[156] and agaric—just as aloes are bitter after sweetness. The reason for the sweetness after bitterness is thin earthy substance along with well-concocted moistness. In fact that thin part is soon lost by being breathed out, but the sweeter part remains—as does a moderate part of moist subtle well-concocted stuff in the case of aloes, but much of the thick and burnt-up earthy stuff.

With ageing in the air, agaric gets whiter and lighter and less unyielding, so that you could hardly see yourself lacking anything in it for perfection, yet the more choice it looks, the worse it is.[157] It is worth while to discriminate by the significant sweetness obvious in the best—ageing makes it more bitter. So it originates, as it were, from the decay of the sap of the larch.[158] Of the same nature of fungi are those that grow on mast-bearing trees,[159] as do holm-oaks, but they do not reach the same perfection nor the same heat, and hence the ones we use for food are black. The feature is common to other trees too. It accords with reason that the mucous stuff of the thickest juice should be the most solid—the drier it has got, and the thinner the juice, the more concocted it will be, so to speak. And so there is also a limit to coction in those that undergo decay; it is actually &544
found that in decay[160] there is not complete rotting.[161] Furthermore, the larch plant is good-looking, with a reddish and perfumed flower. Among the drops of sap which are familiar for their beauty is the juice of dragon's blood,[162] so called from its resemblance to animal blood. It originates in the island of Socotra, with a circumference of sixty miles and located in the Ethiopian Sea, near the promontory of Gingis.[163] The actual tree is remarkable: it rises into a point, like a cone of salt or sugar, narrowing from wide at the foot—with the leaf of an oak.[164] Its sap is an incense of the ancients, "cancamus."[165] Of lacca, which some people have recorded as dragon's blood, there is a good supply in our time, but a huge shortage of genuine dragon's blood.[166]

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[156] Pepper-like, from Sumatra.

[157] Instead of "the more choice it looks, the worse it is" 1554 has "it is totally devoid of virtue."

[158] The following two sentences appear first in 1560.

[159] I.e. those bearing acorns or beechmast.

[160] "situs."

[161] "putredo."

[162] "Sanguinis draconis succus."

[163] *Encyclopaedia Britannica*, 9th edition, suggests that this is Cape Guardafui, the eastern extremity of the continent of Africa.

[164] "quercus folio."

[165] "Cancam*um*" is an Arabian gum, "perhaps Balsamodendrum katuf" (*OLD*) mentioned in Pliny (*Nat. Hist.* 12. 98).

[166] The "shortage of dragon's blood" may be a jest. In the next Book (IX) Cardano mentions a tale of a dragon that sucked out the inside of an elephant, 633 (1560), and later, 643–44 (1560) says that he saw a dragon, while visiting friends.

Aspalathus wood,[167] which is pleasant and cooling, just like rose and vaccinia,[168] and accordingly among the rarities, is also included in the odorous things. The reason is that a pleasant odour is rarely chilly, because it is created by heat, and therefore heat has to triumph—and hence most odorous things, which the Greeks call aromas, are hot.

In santhalum,[169] and vaccinia, which we call blue violets, the heat is only in the thinner part; all the rest is cold because it is thick, and preponderates with its mass. But in these the coldness is not concealed, as it is in roses, since in some people these produce headache[170] by their odour, and in other people too they provoke bleeding from the nostrils. Myrtle[171] too is among the kind of sweet-smelling cold plants, the bush sacred to Venus because of its elegance—it is all odorous, with the wood, the bough, the fruit. And there is a &545 syrup[172] from the fruit. This liquor keeps for a year, just as healthy to use as it is nice to smell. A moss, an odorous plant, can be included partly among these; it creeps over[173] trees, and retains the virtue of those it sticks to. The best grows on a cedar, the next on a larch, lastly the white poplar and the oak. The oak product is worse. What sticks to the larch takes fire very easily, and in burning breaks up and emits sparks. But moss ought to be included with the herbs rather than the trees—it is not even completely a herb.

But aspalathus is in India a tall tree, which in a cooler climate is a thorny bush. In fact everything is taller, juicier, and livelier in the hot and moist regions, unless the plant's own nature prevents it, so that in western India groves of aspalathus can also be found. In the hot and dry regions, the plants are smaller and drier, but the strong ones are weak in wet and cold regions, being full of juice. Those that are hot by nature are tall and spreading, the cold ones are small. Though some too are by nature small, like the hemlock, in a moist and shady place they spread out better, and are also more effective in their powers. According to the testimony of Theophrastus,[174] the Chians used to choose one of this sort, and taking off its bark they mixed the juice with water and gave it as a drink to condemned men, so as to speed them to a painless death. They used in fact to

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[167] Mentioned above, 524 (1560).

[168] "a dark-flowered plant . . . perhaps an orchid or fritillary" or "the whortleberry" (*OLD*).

[169] I.e. "aspalathus"; see n. 52 above.

[170] Reading "capitis dolorem" with 1554, not the "capitis colorem" of 1560.

[171] The remainder of this paragraph appears first in 1554.

[172] "defrutum," used classically of grape juice boiled down into a syrup (*OLD*).

[173] "serpit" is used here as a transitive verb, which is not recorded in *OLD* nor *L&S*, but probably Cardano is thinking of it consuming part of the tree as it proceeds.

[174] The Chian procedure is set out in some detail by Theophrastus (*Enquiry into Plants*, 9. 16; Loeb 2: 305), but he does not include Cardano's own remarks here about emulating death in old age.

emulate the death which occurs in extreme old age—for the distress felt at death occurs through either difficulty in breathing or release[175] of the vital spirit. But when the spirits are released of themselves, they create no distress, as happens in the panting of &546 hard work.

But the cause of the spirit's release (such as fever, a wound) is what usually creates distress. So by introducing a heavy stupor, hemlock juice suppresses the spirits without distress, through excessive cold; the difficulty of breathing is no greater than what corresponds to the scarcity of spirits. The outcome is that death's onset is not harsh, as it is in those who are suffocated in water, and much less than in those who are strangled. And so this death, brought about by hemlock [488]juice, and the one brought about by the unique bite of a viper, on which Plutarch wrote in his life of Mark Anthony,[176] occurs with a heavy stupor, and is extremely like the one happening in advanced old age, so that it is painless too. So it is no wonder that the Chians and Athenians executed with hemlock juice the notable men whom they had condemned to death, so that by the gentleness of their death they gave compensation for what they had taken away from their life and status.[177]

In the province of Peru in west India, there are recently discovered fruits of death—they are berries,[178] and sweet-smelling, which is remarkable; and the tree itself is bushy, with the leaves of a pear tree, thick, close together, and quite green—no wonder that with the diversity of the region such a destructive plant turns up. In fact Persian apples[179] acquired their name in Persia where they first appeared, and after being moved from there since they were lethal in Persia, they became harmless in Egypt.[180] This tree has solid wood, taller than a pear tree, which it closely resembles. It is green with permanent vegetation, and has a fruit not unlike an almond, rather long and green. The stone is that of a plum, but

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[175] "resolutio."

[176] Plutarch describes in his *Life of Antonius* (71; Loeb 9: 301–3) how Cleopatra tested various poisons on condemned men, and settled on asp bite, which "alone induced a speedy torpor and sinking, where there was no spasm or groan, but a gentle perspiration on the face, while the perceptive faculties were easily relaxed and dimmed, and resisted all attempts to rouse and restore them, as is the case with those who are soundly asleep." Any resemblance to old age is not mentioned. Later, he describes briefly the death of Cleopatra from asp bite, and indicates that she was speaking till she fell down beside her bed, but gives few details.

[177] The celebrated death of Socrates by judicial poisoning with hemlock is recounted in Plato, *Phaedo* 117–18.

[178] "sorba," properly "service berries," the fruit of *Sorbus domestica* and allied species (*OLD*).

[179] 1554 uses "persica" here, 1560 "perseae poma," 1550 "praecoqua" (citing Martial for the word).

[180] But 1550 reported instead here that they became harmless in Italy, and even welcome in perfume and taste.

smaller and softer. They mature in the course of a year, one developing to replace another. It is so easily digested[181] that even a large supply does not weigh one down. &547 Thus it is certainly far removed from a peach, since it is established that its trees differ much from the peach tree. They usually get milder on transplantation, and some turn out worse. Thus though the fatal fruit carries a deadly juice, which smeared on arrows brings instant death, without means of escape,[182] the tree creates a shade which bloats the whole face and eyebrows, and covers the eyes over; the dew falling from the tree, if it gets into the eye, leads to blindness by ulcerating the cornea. While the wood burns, it evokes headache and a filthy stench. The[183] oleander does something similar among the inhabitants of Sardis; it is not harmful only while being eaten, and if someone takes a rest under its shade, he goes mad, is agitated and restless, and experiences rumbling in the stomach. But people who enter a bath heated with its wood usually suffer syncope. Pietro d'Abano[184] vouches for having seen most of this; such things occur because rarefied moistness, and a proportion well concocted and odorous, get mingled with much that is thick and destructive. In our neighbourhood the service berries turn unwelcome on taste alone, since the matter of deadly moistness cannot be rotted away by the heat of the ambient air.

But[185] after we mentioned that the shadow of this tree is harmful, and since many people have experience of the destructive shadow of the walnut, explaining its cause will be relevant. The whole walnut plant is cold, and smells bad, particularly the leaves and even the twigs, so that many vapours emerge from it, of which there is &548 always a large supply underneath the tree. And the plentiful thick leaves do not allow the Sun's power to remove these vapours, so that the shadow is harmful to sleepers, and the location even more so; indeed, the sleepers are colder in their brain and external parts, their heat being summoned back to the heart. As evidence there is this, that the Moon's light leads to haemoptysis in them, but not in those who stay awake. Troublesome weariness contributes to this, and pre-existing agitation, and weak and moist bodies, such as boys have, and bodies full of evil humours, and prolonged lingering.[186] When this happens, the victims look star-struck—some are stupefied, others develop prolonged fevers. This is the basis of the view that dead men dwell under nut trees. So it is not the shadow that does the damage, but being close by; the shadow is a sort of deprivation.

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181 "concoquitur."

182 "nullo redimitam auxilio"—but Cardano means "redemptam," not "redimitam," which means "garlanded."

183 The following three sentences appear first in 1560.

184 Peter Apponensis: this is Pietro d'Abano, author of the *Conciliator* (Venice, 1476). See n. to Book III at 246 (1560).

185 This paragraph was introduced first in 1554.

186 "diuturna mora."

Very close to poisons are the lymphatic[187] plants, such as the Cohobba[188] in the island Hispaniola[189] in the West Indies, which inebriates by its odour alone, and makes men frantic.[190] I think this herb is of the thorn-apple[191] kind, which when drunk produces a brainstorm[192]—no different in its powers from the one that the Turks call asseral,[193] of which they make great use, because it not only makes them cheerful and eager, but also drives away all anxiety and fear, making them also more prepared for military duties. With us, crocus is like this; if it is eaten too liberally, as with asseral, it makes people not just eager, but drunk; with even more plentiful intake, it kills. Similar are wine, and the wine products alcohol and dregs, when drunk, and as is reported long ago, the root oenopia,[194] a name acquired from some resemblance to wine.[195] &549 In the past, on the authority of Joseph the Jew, the root Baara[196] was of the colour and brightness of flame, which brought death to those who handled it unless female blood or urine was poured over it. But even then it was deadly to those who are tearing it away, hence it used to be torn out by a dog, which would die when it had been torn out. When hung up, it used to cure demoniacs and distraught people.[197] Is this then utterly fabulous? Surely not, with so serious an author. Is the tale true? Not that either—it is too close to a miracle. The basis of the thing needs to be weighed up, from which an image of the truth will shine forth.

First of all: Judaea is a region extremely hot, and almost all mountainous. Baaram[198] is a valley after which the root is named, a valley rich in pitch, and

[187] "lymphaticus" in Latin means crazed, distraught, and is so used by Cardano, 549 (1560) just below.

[188] *Encyclopedia Britannica* describes Cohoba as a hallucinogenic snuff made from the seeds of a tropical American tree (*Piptadenia peregrina*) and used by Indians in the Caribbean and elsewhere.

[189] On Hispaniola see n. to Book II at 127 (1560).

[190] "phanaticos."

[191] Reading "stramonium" instead of the "strimonium" of 1560.

[192] "in furorem vertit."

[193] Possibly hashish, the leaves, shoots, or resin of hemp (cannabis).

[194] This word is an old name for the island of Aegina off Athens, but I cannot identify any appropriate meaning here.

[195] The Greek οἶνος means "wine." The rest of this paragraph together with the four subsequent paragraphs was first introduced in the 1554 edition.

[196] See nn. 198 and 203. .

[197] "lymphaticos."

[198] See Josephus (*Wars of the Jews*, 7. 180; Loeb 3: 557–59): "In the ravine which encloses the town on the north, there is a place called Baaras, which produces a root bearing the same name. Flame-coloured and towards evening emitting a brilliant light, it eludes the grasp of persons who approach with the intention of plucking it, as it shrinks up and can only be made to stand still by pouring on it certain secretions of the human body [The Greek identifies these as female urine and menstrual blood.]. Yet even then

the part of the pitch that is thoroughly heated and very rarefied used to trickle down from the mountains. It was credible that it was created from this matter, matter burning and so thin, in between the utmost solar heats, and not in every spot in the valley, but either under the actual solar heats, which simultaneously intensified and concocted it, or else in permanent shade, so that none of its poisons would be entirely blown off—this herb used to arise and be nurtured by fiery substance. When it was pulled up, that notorious burning rotten vapour (we said that what is rotten to one person is natural to another) was picked up by the brain, and it used to kill outright either the men who pulled it up or the dogs standing by.

But if the root was drenched with female blood, the poison was blunted by that rottenness (or by the acidity of urine, if urine was easier to handle like this).[199] The superstitious had added that however it killed, even if it were pulled up far off, the occurrence passed beyond natural &550 causes into a supernatural manifestation[200]—that was always people's way, even though this view was false. Unless maybe, as we said in connection with poisons, some things are transferred by the continuity of a thing, as we will explain too in relation to the stupor of lethargy,[201] and in this way deadly power creeps along a rope and kills at as great a distance as you will—that could come about. That when hung from the neck it would cure distraught people or demoniacs is partly credible, because it would possess such great powers, and it would be convincing that all very excellent things are accompanied by great difficulty and risk, though not [489]everything achieved with great difficulty and risk is excellent. This view has been reinforced by people's superstition, which as I said was always vast, like their ignorance. In fact, there is no people so repelled by studies[202] as the Jews, totally absorbed in their ceremonies and law. So it is no wonder that Baaram had such power, for even now it is not at all safe to dig up monk's hood.[203] Just arrange the species of

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to touch it is fatal, unless one succeeds in carrying off the root itself, suspended from the hand. Another innocuous mode of capturing it is as follows. They dig all round it, leaving but a minute portion of the root covered; they then tie a dog to it, and the animal rushing forward to follow the person who tied him easily pulls it up, but instantly dies—a vicarious victim, as it were, for him who intended to remove the plant, since after this none need fear to handle it. With all these attendant risks, it possesses one virtue for which it is prized; for the so-called demons—in other words, the spirits of wicked men which enter the living and kill them unless aid is forthcoming—are promptly expelled by this root, if merely applied to the patients."

199 "vel acredine lotii, si lotio atque ita tractabilior erat"; the syntax is unclear.

200 "religio."

201 "torpedinis"—just possibly, "of the electric eel."

202 "disciplinae."

203 This was the time-honoured reputation not of monk's hood (*napellus*) but of mandrake (*mandragora*); Pliny (*Nat. Hist.* 25. 94) advises diggers to "avoid facing the wind, and first trace round the plant three circles with sword, and then dig while facing the

plants, and the regions, and the nourishments: what is more likely than what up to now was reckoned in the role of a miracle or fable? And it is no wonder that a plant is nourished by pitch—one is nourished by sulphur too. Aristotle recounts that little herbs grow in sulphurous springs; when the winds blow, the sediment from brass drops out, which they call orpiment,[204] it decays, and thus the herb originates.[205]

Plants are propagated in five ways: by seed, by root, by stolons, by tying-off,[206] and by decay, which we can properly[207] call chance. &551 Most of them by seed, such as fir and larch; by root, like liquorice and lily. A lily has such vigour that when its twigs are hung up, they put out a root. Theophrastus supposes that a drop of sap[208] gathers, and from it propagation occurs, which is quite true.[209] In addition, the knots of this plant can be hung up under a stove, even without leaves, and then after drying they are covered in the dregs of red wine; and when buried in dung along with the same dregs, they give forth purple flowers. And bunches kept a whole year in earthenware vessels stay in flower, so long as they are kept moist with tepid water. And no wonder—the cause of all this is a single one: moistness that is strongly fatty. The evidence is that in small bedrooms flowers keep for virtually a whole month, and the so-called substance of the humour is sluggish. Even God Himself vouches for this being a flower of great beauty:[210] it is of itself very shiny white.

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west." This manoeuvre can be traced back to the interpolated 9th book of *Enquiry into Plants* by Theophrastus. Cardano does mention mandrake in Book XVIII of the present work, 1161 (1560) and 1168 (1560), but not in this connection. Arber (*Herbals*, 7–8, 39–40, 123) sets out the story of the durable mandrake superstition, relayed especially by "Apuleius Platonicus" whose *Herbal* was first printed in Rome in (probably) 1481; the superstition was being denounced as a hoax in 1526, but survived somewhat longer. On monk's hood, Cardano has remarked earlier that "Also before the flowers of monk's hood open, they display the likeness of a dead man's head, or rather of a skull. Its root is actually quite lethal," 532 (1560).

204 "auripigmentum," i.e. the "gold-coloured pigment," arsenic trisulphide; see n. to Book II at 196 (1560).

205 See Aristotle, *De plantis*, 2. 4; 826a1–8; Loeb 209.

206 "ablaqueatio"; but see Plin. *Nat. Hist.* 16. 116, where the word appears as its verb form and is applied to soil; it is translated there as referring to "loosening the soil at the roots," with which *L&S* and *OLD* concur; however, in view of the use of this word a little later on this page, for Cardano I think it must mean the obvious "tying off," derived from "laqueus" = noose.

207 "merito."

208 "lachryma."

209 Theophrastus (e.g. *Enquiry into Plants*, 6. 6. 8 and 9. 1. 4; Loeb 2: 43 and 221; he writes the Greek δάκρυον, the equivalent of Cardano's "lachryma") supposes that a drop of sap ("lachryma") gathers, and from it propagation occurs,

210 Matthew 6: 28–29; Luke 12: 27.

But in Italy the iris flower is at times shiny white. Some plants are propagated by all the methods, such as the olive, and the fig, which alone among the plants of rather valuable fruit in not flowering. But we have explained that all plants are generated of themselves,[211] since there is concoction everywhere, and the stems appear to need soul only. And the Sun is soul. The willow appears from a twig, as does the vine too. It is a kind of tying-off,[212] and special for the vine, when the trunk is buried for two years, and by sending forth a root it is cut free from the previous one. The ancients teach that the same happens from tree into tree. Thus it is agreed that plants are nourished by fatty moistness, as we will explain later.

&552 But returning to odorous plants: the lilies, nard, and crocus are of this kind. Italian[213] nard is a small bush with leaves longer than those of rosemary, narrower, rather thick, softer, perfumed. The flower is quite small, and between blue and purple. The trunk and branches are woody, it stays green in winter—if the winter is rather severe, it dies. However,[214] what we call the Indian one is of another kind. Nard is in fact the latter, not the former—a plant of its own kind, taking its name from the sweetness of its odour—it lacks a spike.[215] Common to them all are leaves that are narrow because of dryness, and a pleasant odour. All plants have the same reason for their leaves: to disperse the cold.[216] This is why in cold regions straw is pulled over the branches and trunk, with the roots in horse dung, the whole tree placed in a hot chamber,[217] and it is not surprising that their leaves are kept from being shed, but the trees even produce fruit. Even with us, the leaves are also retained in the spontaneously hotter and drier plants—nard, rosemary, salvia, juniper, laurel, cypress. But in the case of box, it actually is bitter, because of its unique violent dryness and medium heat. In India, a very hot region, no tree's leaves are shed, except those of the pulse we call cassia. Since it sends roots underground right to the water, it is accepted as cold by nature, and moist on a triple basis: it has sucked up quite plentiful moistness, its root is far from the Sun's heat, and it is chilled by the cold of the water it touches.

So[218] that differences may be assumed in plants from the nature of the leaves, there are five kinds of plants. Some are &553 permanent, but do not thrive with

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[211] "sponte nasci."

[212] "ablaqueatio"; whatever this word means classically, as mentioned earlier (n. 206), surely for Cardano it must have this pretty obvious meaning.

[213] 1550 and 1554 read here, "omnis," not "Italica."

[214] The three following sentences are absent in 1550 and 1554.

[215] "spica"; this is an odd remark; nard in general was at times described as "spikenard," for instance by Celsus (3. 21. 8: "rosae folia et nardi spica").

[216] Puzzling syntax: "Eadem causa est omnibus plantis folia amittendi frigus ipsum."

[217] "hypocaustum."

[218] This paragraph appears first in 1560.

the same foliage, as with laurel, and all the sorts of citron—as more grows up below, the original foliage falls off. Others do thrive with the same foliage, as on the palm, and this is very uncommon. Some are always thriving, but not with the same leaves or branches, like salvia and house-leek. Some, such as the cherry, lose foliage, with the same leaves and branches persisting. Some too are stripped with their trunks, like fennel. Of these some die totally, like the gourd. So we need to have accepted that number of kinds.

But to return to the odorous items: the crocus has a bulbous root, ample, vigorous; leek-like leaves, but so narrow that they can be called long-haired. The stem is blotchy, the flowers of a wine-like hue, like meadow saffron[219] blooms amid which the flame-like stamens of crocus arise. Balsam too used once to be costly. It is agreed that there was a bush with the leaf of sweet marjoram,[220] and of nearly the same kind, and nothing closer, with a plant not much different from jasmine. But[221] all the bushes have completely perished, states Peter Martyr d'Anghiera[222] our fellow citizen, after performing the function of an embassy on behalf of the Kings of Spain to the Sultan the master of Egypt, nearly fifty years ago. Others relate that it is so widely propagated that it is found everywhere in the gardens of Cairo.[223] But I do not see why Anghiera should lie to his kings to whom he dedicates the work, or should have dozed[224] in a matter of such importance. Everyone's evidence—even that of those who want there to be propagation—concurs enough in this, that from that time neither fruit nor wood, much less that famous juice are exported to us. So the conclusion is that genuine balsam &554 is no more, and that something else has supplanted it, through the enterprise or greed of the inhabitants.

To continue: the jasmine flower is very shiny white and perfumed—one blue, another tawny, which I recall seeing. It[225] generally flowers in spring with the roses and the other garland flowers.[226] But I saw one which had been brought from Spain in the month of September. It is a shrub, but extensive and pulled out and tied up; though slender, it matches the trees in size. And it is not of a kind with the snakes, since it has no tendrils like a vine or bryony or a gourd, nor is it a tree rich in roots,[227] like ivy. It can accordingly change readily into an upright

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219 "colchicum."

220 "sansucus," more conventionally "samsucum."

221 The statements here about genuine balsam being no more first appeared in the 1554 edition. The account of balsam in the 1550 edition differs considerably.

222 See n. to Book II at 127 end (1560); here his *Legatio Babilonica*, 3, in *Opera* (Graz: Akademische Druck- u. Verlagsanstalt, 1966), 29.

223 "Chairi."

224 "oscitaverit"—precisely, "yawned."

225 The four sentences which follow modify and replace a single one in 1554.

226 "coronariis."

227 "radicosa"; these will be the attachments to the parasitised tree.

and presentable[228] tree, with minimal trouble. With a green soft thin darkish leaf, almost like an [490]olive tree's; the flower is in little "umbrellas."[229]

It is certainly extraordinary that it has no fruit and no useful application—like no other more notable flower—the lily, crocus, rose, eyebright, clove. People think the cause is that the whole of its virtue is consumed in the flower; or since the times for flower and for fruit are different, the fruits consist of moist and thick substance, so as to be noteworthy, but the flowers of hot and dry substance. Thus it is very difficult to find a tree of such variable temperament that it can meet both needs at their appropriate times. Thus it is rare for a famous son to be born to a distinguished father, and for an honourable old age to follow upon a noble-spirited childhood—a sequence Philostratus the sophist mentions too in the case of Hermogenes of Tarsus.[230]

&555 To finish off the account of the good-smelling plants, basil[231] needs mention, because this herb smells good, and springs up everywhere, so that all of Ethiopia has it in profusion. Nature seems to have devised a liberal supply of useful plants, for good reason. Since some of them are profuse everywhere, they look different through change of colour—for instance galingale[232] in Italy, galanga[233] in Babylonia, and turmeric[234] in the intermediate regions—they are the same in faculty and nature, but in form and powers they differ; Galanga is in fact as much sturdier than turmeric as galingale is weaker than it. But galingale appears more odorous than turmeric. Yet we have explained previously that plants are diversified by climate and soil. And similarly with fruits: ben nuts[235] (I shall not speak erroneously of "myrobalanum," the acorn of the ointment)[236] belong to the plum kind, and these, as Aristotle records,[237] are sweet before ripening. They arise in very hot regions, from watery and not fatty moistness and rarefied substance, and

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[228] "elegans."

[229] "umbellis."

[230] This child prodigy in the second century A.D. was admired by Marcus Aurelius, and though Philostratus (Flavius Philostratus, born about A.D. 170; for details see *OCD*) thought little of his adult rhetoric, he did write books later, some of which survive (see *OCD*).

[231] "Ocymus."

[232] "Cyperus," classically "cyperos" or "cyperum." Galingale is a rhizome with a hot gingery-pepper flavour, used in medicine and cookery (Cook, *Matters of Exchange*, 86). This gingery herb is nowadays familiar in Thai cuisine.

[233] "greater galangale."

[234] "curcuma."

[235] "myrobalani," apparently masculine plural, though classically the word is neuter.

[236] Castelli remarks confusingly that "myrobalanon" is synonymous with "glans unguentaria" and is of five sorts—and differs from "glans vel nux unguentaria."

[237] "The fruit of the ben-nut tree is sweet at the beginning, when it first appears, but generally speaking they are astringent, and when mixed, bitter": Aristotle *De plantis*, 2. 17; 829b34–36; Loeb (in *Minor Works*), 233.

are concocted and perfected very fast, on the opposite plan to tamarinds,[238] which always stay bitter and acid, because of fattier moistness and earthiness. They arise in a part of Ethiopia called Bernagassum, beyond the tropic of Cancer next the Red Sea, in the more western part between groves, from a very large tree bearing fruit like bunches of grapes. Their[239] stones are like beans in size and shape, and in their skin too, except that the colour is rusty and dusky. &556 A part presents the shape of an egg, with dark lines, as you see at the side, drawn across it. The skin of the stone is very bitter, the core is white, hard, tasteless. The fruit is oblong, large, not unlike a plum.

Nature's works are marvellous, and its industry recalls to memory the fruit of the Balsamina, so called because of the similarity of powers and of the plant.[240] The fruit in fact heals fresh wounds very quickly, and the tree itself creeps about, as of yore balsam did, making its way up posts which hold it up. Remarkably, its fruit, which is red, and virtually like the Halicacabum,[241] splits totally apart of itself, if it falls to the ground and is slightly disrupted. The reason is that it consists of rather soft substance, and is held in by no breadthwise fibres, which makes it split from the impact; ice too is divided in the same way, if a part of it is broken off, since it entirely lacks hairs, and gapes from its weightiness, which makes it break up entirely when cracked. Parts are over-weighty, and since they are straight, they are parallel, and are divided as a whole.

On account of these two causes, these things divide lengthwise, when breadthwise fibres are absent. Consequently the medicament must be dry—dry timbers are divided when a part is divided in this way. But in timbers which possess breadthwise fibres, the intact part keeps the divided part together—in the balsamina fruit, the divided part separates the intact part.

&557 But to return to my topic: balsam has really nothing in common with this, but the actual juice was of a golden colour, and very suitable for the healing of wounds; it used to abolish wrinkles, and protected the face of corpses from corruption, and crumbled kidney stones, and removed blotches from the eyes, and was resistant to poisons, especially aconite, and to febrile rigors, and in all these points the powers of balsam used to stand out.

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[238] A large tropical tree with yellow flowers and long brown seed pods, containing a pulp used in drinks and medicines (*Chambers' Dictionary*).

[239] The following four sentences were first introduced in 1560.

[240] Of the balsam, presumably.

[241] ἁλικάκκαβον, "a name of various plants, probably a) winter cherry, *Physalis alkekengi*, and b) sleepy nightshade, *Withania somnifera*" (*OLD*, citing Celsus and Pliny).

And now another kind of balsam is imported from Hispaniola,[242] of the colour of jujubes,[243] bright and tenacious, of a marvellously pleasing odour, so much so that no one would suppose how attractive it is. We saw it at the place of Sebastiano Serlio of Bologna, the royal architect at Lyons,[244] certainly a gifted man, and fond of us, and we handled it there. I had seen it elsewhere at Genoa (or Ianua), because it smote the tongue like pepper—but I think that one was spoilt by fire; it had a sort of burnt and heavy smell.

Whatever this may be like, it does heal fresh wounds better, indeed as well as anything does, and removes wrinkles. I could believe that this kind of oil is effective for most, if not all, of the purposes that genuine balsam serves.

It is related that Codrus,[245] an Italian physician, found it, a man who was so very eager in seeking out novelties that (being very rich) he passed away in old age in a part of the new Southern World near the harbour of Pumida and the islands of Zorobarum.

&558 So to return to my account: the tree which produces this oil is Goacomax, in shape and size almost similar to the pomegranate tree, but with a leaf a little larger and thinner, with a bark virtually dry, with wood that burns like a pine-torch, fruits like bunches of grapes, but with the berries wider apart and slightly larger, of a wine-like colour, which after prolonged stewing in water along with the twigs yield this kind of oil. Thus an oil is easily extracted which reproduces the odour and powers of the plant, among those which contain oil in plenty. Oils[246] are actually created either to preserve a substance or to take up powers. A power is taken up by a different oil—either all at once,[247] as when four times as much water is added to oil, or more or less so—less, in dealing with flowers and leaves, and more, in dealing with wood; midway, in dealing with roots and fruits; then they are boiled down with fire for so long that all the water there is is removed. If the plan is not to do the taking up all at once, this will happen more conveniently with a moderated heat—either the Sun's, or the heat of ash or of a bath, or of [491]dung, or of the refuse from wine-pressing or olive-pressing.[248] From all these, ointments can actually be made.

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[242] See n. to Book II at 127 (1560).

[243] "iuiuba."

[244] Sebastianus Serlius, b. 1475 at Bologna, died 1554 at Lyons. He was architect to Francis I of France, and published one of the most widely used architectural treatises of the early modern period. He was also an architect of some renown. See *Enciclopedia Italiana* for details.

[245] Not identified.

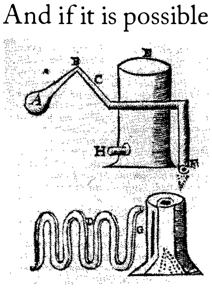
[246] 1550 remarks here that if the oil is not plentiful, there are three ways of extracting the scent and the powers, and then proceeds at once to the method of Dioscorides.

[247] "repente."

[248] "vinaceorum aut fracium."

And so in this commoner, second and more ancient method of Dioscorides, flowers used to be immersed in pure oil for four days, and to be exposed to the Sun; then, the same amount of fresh flowers used to be added with great care to the oil that has been expressed, and it was exposed once more to the baking hot Sun. It was permissible to do this often enough for the oil to pick up the odour; improving agents[249] were added for ointments, such as from honey and other odorous items. The[250] third method requires no &559 heat, but on the other hand needs more numerous repetition and longer delay. And so the flowers are handled on this pattern: scatter the flowers on almonds, or—far better—on cleansed granules of ben nut (they do not turn rancid), or cinnamon or crocus (the method is the same for all), and arrange below them alternately leaves of flowers and of almonds, and keep them squeezed long enough for the flower odour to vanish. Then throw them away, and instead of them put other flowers underneath, on the same pattern; and repeat this so many times. There is not the same pattern in all cases, until the almonds have picked up the maximum odour, then put them under a press. It is well to strip them of skin first, and roast them a little; that way, the oil picks up more of the powers, and is less liable to corruption, because none of the juice is left in it.

There are as many ways to extract the oil's substance as there are to extract its powers. While the substance is not to be had without the powers, the powers can be had without the substance. But is there some oil without powers? It is beyond doubt that when extracted with a large amount of fire, they are burnt up, and do not retain their special power. The kinds of thing that are extracted all at once and through the fire's actual power belong to the first method. It is unsuitable for flowers, but suitable for woods and their like, such as cloves. In the glass vessel A, ground-up items are placed, and are distilled with a proportionately milder fire. And if it is possible to coax out the oil with boiling water placed round the vessel, it will be much better.



&560 A glass cap C is placed on the top of the vessel, and the wider it is, the better it is for transferring powers, odour, and taste. The same is placed in both channels. The cap is accordingly fitted in place with clay, to prevent it leaking vapour.[251] A pipe C lies against it in the usual way, and to it another glass pipe D is linked, sealed with clay so well that no leak can occur. It passes through a wooden vessel

[249] "spissamentum"—in *OLD* and *L&S* this means only a stopper or plug, but since "spisso" means "to thicken," the meaning of "thickening agent" might be suspected. Castelli, however, regards the word as synonymous with the Galenic Greek στύμμα, and meaning "agent that preserves the perfume and delays deterioration."

[250] At this point 1550 includes material on a second method of extraction, present later on in the lower part of 565 (1560).

[251] "ne respiret."

E, which ought to be kept &561 full of very cold water all the time, drawing off through a tube H any that has taken up heat, and topping up with newly-drawn fresh water. D is in fact chilled, and the fumes are not burnt up, but transferred into water or oil, and are directed along the oblique part of the channel F which is set ready beyond the vessel full of water, and drip into the vessel G.

So as I have seen, first of all a turbid stuff flows out, carrying with it the thinner substance of the load,[252] thereafter clearer water emerges, finally oil, which emits rather the smell of something burnt than of the load from which it flowed out. And[253] the channel D can be shaped into the likeness of a snake, and thus less will pass through from the substance or the virtue of the load.

The second method corresponds proportionately to the other one: with the use of a more moderate water heat, items boiled produce an oil, as we mentioned not long ago in the case of Indian balsam. On the same basis, an oil is also extracted from laurel berries. Thus in general, in these cases the substance should be fatty and readily separable. But once compacted by cold and dryness, it could not be dissolved or separated otherwise than by hotness and wetness.[254]

The third method consists not in heat but in force; it is common to all fruits, such as almonds, pistachios, nuts whether they are walnuts or filberts or even Indian ones, also nutmegs[255] and those smelling of musk,[256] and others without number—say pine nuts, pepper, ivy fruit, peach and cherry stones; further, all seeds, such as those of turnip,[257] castor oil plant,[258] radish, flax, henbane,[259] poppy. These ones are &562 celebrated, and both they and all other seeds contain an oil. For there is life in every seed, and all life resides in moist fattiness, and everything fatty (in animals too) is called fat, of which there are three sorts: "pinguedo" from the name of the kind, "adeps" which surrounds certain parts, and is not common to the whole—such as renal or omental fat—and "sevum" which is drier than either, so that it occurs only and maximally in horned animals, and is what is present in things devoid of sensation, such as stones, and parts of plants—indeed, the whole of plants, also in pitch and salt, metals and a number of other things, and it is called oil. And the sap of every single tree is an oil mixed with earthiness. Thus every seed contains an oil. It is accepted that all seeds derive their life from this, that in the view of Theophrastus, from all seeds

252 "res."

253 In 1550 a passage opening in 1554 and 1560 at [E] on 570 (1560) appears here instead .

254 Syntax contorted: "sed et frigore ac siccitate coactam, neque aliter calido et humido solveretur aut separaretur."

255 "myricis," evidently synonymous with "myristicis."

256 "moschatis."

257 "rapa."

258 "ricinus."

259 "Apollinaris herba," *Hyoscyamus niger*.

plants of their kind are produced—or that will happen from all of them, or the majority; in fact there is nothing to prevent some seeds being damaged in their whole kind, since there are some animals too like that, such as moles, and those plants would spring from decay, or from a root, or by some other method than a seed. What I mean by a seed is what is covered with some shell—a fruit is what is not so covered.

Consequently some seeds are in little sheaths—for instance French beans[260] and chickpeas. There are some sticking to the beard[261] of cereals, and most of those with a thin skin, such as corn. But those [492]in fruits, such as the seeds of melons, apples, and pears, are contained by pericarp.[262] Every seed, too, is the hottest part of its plant, which has been brought about for the sake of generation, but is not &563 the most acid, nor the most rarefied, nor the driest. The root of many things, such as fennel, the pod and the skin of many plants, such as the unias,[263] which the Indian inhabitants of the island of St Thomas[264] use instead of ginger, is very acid, though the seed is tasteless. Heat is actually moderated by plenty of fatty moistness; hence a good supply of oil trickles from it. In the skin it is burnt up, as in distillation, since there is more earthiness in it, but not in the simple sense: the skin of the Indian bean (which we deal with below) is rich in plenty of oil, but the stone is not, since because of the abundance of moistness it cannot concoct oil nor mould it into the form of oil.

Some of the seeds contain a lot of oil, as do the nut and the seed of flax and heliotrope and turnip. What I actually call the nut is the part which is held within the whole fruit—the nut is, as mentioned, what contains the seed. However, since it is normally eaten, most people call it the fruit.

Some people call a big seed the fruit, others whatever is in the end produced and eaten from plants; and what is in the end produced and not eaten, they call the seed. But as I have said, there is not a special difference between seeds and fruits. Turnip seed produces so much oil that in some regions of Germany it not only meets the need of the natives but is also exported for profit to towns nearby. In Ethiopia there is a huge supply of the herb Henna, and from its seed an oil is extracted which is not only in great abundance but also excellent. &564 Reason teaches us that in anything containing a lot of oil the oil is also an excellent one.

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[260] "phaselli."

[261] "arista."

[262] The following four sentences first appeared in the 1560 edition.

[263] John W. Blake (*Europeans in West Africa*, 2 vols. [London: Hakluyt Society, 1942], 1: 78–79), in connection with a late 16th century Portuguese voyage to Benin in West Africa: "There is another tree that produces long pods like those of beans, with some seeds inside, which have no taste, but when chewed they have a delicate taste like that of ginger. The negroes call it *unias*, and they use it as seasoning, together with the said pepper, when they eat fish, which they are so very fond of."

[264] St Thomas is in the Virgin Islands, in the West Indies.

For the sources of an oil that is not only plentiful but also excellent greatly need a well-tempered heat and a great deal of moistness. Yet in some that hold little, it can be excellent, but nothing stops it being very bad. So the excellent can co-exist with both abundance and scarcity, but the inferior almost only with scarcity; for as I said, in all cases some monsters appear which are the work of nature. Nothing actually prevents something existing which abounds in plentiful oil, yet the same oil being bad or smelly or useless, because not brought to completion. Whatever is fully concocted is brought to completion.

But back to my topic. The oil is coaxed out by the power of an oil press. And however manifold this procedure may be, it would suffice to explain it by three examples. The first will be that of the nutmeg, which is divided into small slices, and these have Cretan wine poured over them for three days, they are dried in the shade for two days, and are warmed in a frying pan, and sprinkled with rose water, and compressed. But if you want to extract an oil that is more plentiful but less effective and attractive, crush the sliced nut, sprinkle it with Cretan wine and pour the wine over it, and put it out in the Sun, till it acquires a crust. Then you will mix it again without pouring Cretan wine on it, but sprinkling it, and dry it again, and repeat this so often till it virtually rots; then it gives oil in plenty. This method will do justice even to the seed of henbane and of poppy—but use water instead of wine, and &565 let it continue till it rots, and then put it under the press. It is in order to wait till rotting in the case of oils which are not drunk.

And this is the second example: because henbane seed is much more moist than nutmeg, as it is than almond, it is fattier than that seed. Hence the third example is in almonds, which after being cleared of their double skin are roasted a little, then a fifth part of water is poured over them, which is a method common to the seeds too (use wine for nutmeg), then the mass is heated by fire and compressed straight away; because it is drunk, it gets rancid while left to wait. Obviously these methods need heat and water; unless an oil liquefies, it fails to flow, for a coagulated thing cannot flow. And what liquefies needs heat—but heat uses up oil, which is why water has to be added, or the oil will be scanty and run out scorched. This is more necesssary in the drier bodies, such as nutmeg; in that case wine is added, because it accentuates rather than blunts the odour; the others have a heavy odour. But wine also makes its way more into the interior, and dissolves it, because it shares the heat of fire. Fire, however, also draws outward from the internal parts. So the oil is not produced from the water or the wine, but they are its defences.[265] It is a matter of doubt whether some part of the water or the wine can cross over to become oil; oil does consist of watery and airy moistness. Where moist airiness is effective, water acts easily, and wine passes over into oil more easily, for wine too can take fire. There are things &566 so oily that when crushed and warmed with natural temperate heat, they pass

[265] "propugnacula."

over into oil without squeezing, because they are extremely fatty, and abound in plentiful oil that has little earthy waste. For instance, elder flowers. Again, the oil extracted from almonds without the use of fire is much more pleasing and does the chest more good.

But there is another mucous humour present in almost all roots and seeds. Among those that are more renowned are the seeds of flax, marshmallow, fleawort,[266] horehound,[267] quince, pear, apple, fenugreek. Also among the roots, all those that are more mucous, such as those of marshmallow and birthwort.[268] From all these this part can be removed, since it is naturally implanted in them. After cleansing they are replaced in a vessel, and by weight four times as much hot water is poured in, and they stay there overnight. Then the water is disposed of, and the roots or seeds are taken into a bag of hemp, or occasionally of linen;[269] the upper mouth is tied and a vessel placed underneath, and a mucous juice is collected, partly by striking it with a stick and partly by hand squeezing. To get all that has run out of it, it is easily tied up tighter, and in a similar fashion squeezed out little by little, and once more tightly tied, till only the actual seed remains. It is a good idea to ponder what this matter is that runs out in this way. This can be reckoned from the powers and substance, and from the mode of extraction.

Since it can soften things, and is sticky, and is &567 drawn off by [493]hotness and moistness, it is agreed that a part is of more fatty juice, and differs from an oil in this point alone, that it includes an earthy part in itself. But this part is thick if compared to an oil, an oil in which there is very little earth. Consequently when this part is removed, seeds or roots contain less oil. Roots therefore contain oil themselves.

There is another distinguishing feature: the mucous juice is colder and more raw than oil, and hence more plentiful in roots in which there is not much oil. There is therefore an oil made, so to speak, from mucous juice, in such a way that what was originally in the roots is now in the seeds. Hence because flax seed is rich in this mucous juice, it produces too an oil without water, because in it juice takes the place of water—and we regularly use this oil against pains, as it is purer. The same applies in the case of almonds, but not quite so obviously; they actually contain little mucous humour, but on the addition of water, quite a plentiful (if not always a better) oil is acquired.

The recalling of all this summons me back to write down the methods by which fats are permeated with odours, so that practices in disuse for many centuries (it always interested us) could be restored to practical application. So to fat cleansed of all membrane there is added a portion of sweet marjoram crushed

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[266] Probably the plant *Plantago psyllium* (*OLD*); Cardano spells it "psilium."

[267] "marrubium."

[268] "aristolochia."

[269] "linóve raró," which might mean "or exquisite linen," but then the final "o" of "raró" would not be accented.

with flowers, thyme,[270] myrtle, galingale,[271] and an eighth part of lemon[272] aspalathus.[273] Also a part of odorous white wine, and water in proportion to everything's weight. This is to be cooked all together, but not for long, and then be left alone for a day, and all sieved after clearing the fat. The same additions are to be made &568 afresh, or two or three of them, or one in accord with the nature of its odour; and with the addition of wine and water as before, the preparation is to be boiled in the same way, is to settle, to be cleared and sieved; and this is done so many times, until the fat has drunk in the perfume. In this way it is permeated with other odours too, and is preserved not only through the heat of fire but with water carefully squeezed out, and is dried in the shade. As I mentioned, only watery moistness decays. Because fattiness is corrupted, it has to decay. There are then moist things of four kinds included in mixed things: either the completely raw, and they are called watery; or the completely concocted, and they are called fatty; or those concocted to an intermediate degree, and they are called mucous; or those concocted beyond the limit—this is the part the alchemists call fire, particularly if it requires much fire during its extraction, as with metallics, while the harsh moistness is taken out with reflected fire.[274] It is therefore clear that there can neither be more nor fewer kinds of moist things.

But in some mixed things there is nothing to prevent some of them being absent, yet all genuine mixed things have three of them at least. In most metallics, the middle one of them lies hidden. As it is linked to earthiness, the last one cannot readily be removed. So when fires are applied, doubt arises whether it is harsh of itself, or through fire's power alone, or in both ways. And the further they are from the original kind of moistness, the less they are exposed to decay. Watery things, then, decay both quickly and completely; mucous things completely, but slowly; fatty things both slowly and incompletely; &569 burned things neither completely nor incompletely. Among the types of flesh, whatever is fatty is extracted according to my usual method, and cut into slices, and shut in a glass vessel. This is covered with parchment and placed in boiling water for six or seven hours, and nearly all the flesh passes over into fat and is liquefied. Tartar is liquefied by moistness, whether buried in marble under the earth or receiving in glass the fume from boiling water. Another method: as my father did,[275]

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270 "serpillum."

271 See n. 232 above.

272 "citrinus," as an adjective applying to "aspalathus," though this word is not included in *OLD* nor *L&S* nor Castelli.

273 See n. 52 above.

274 "igne reflexo"—possibly an alchemical term.

275 Cardano's father Fazio was a jurisconsult by profession, and also had a serious lasting interest in mathematics, especially geometry. But Cardano's biographer Henry Morley mentions no interest in chemistry or related studies. Mention of Fazio's method first appeared in the 1560 edition.

submerge a heated pot with tartar in water, and at once oil will come to the surface; by these methods many things reduced to lime by fire are changed into oil. Hence it is unclear whether this well-known juice of tartar is oil, or rather water. Sulphur passes over through burning into oil; the fume that is collected while things are chilled makes an oil, as I have found. A unique vessel is required, all of glass, which is called a "nola."[276] And diligence is used to make the burning gradual.[277]

But why do burnt metallics yield oil more easily, and also hold on to water? The water is extremely harsh. Is it because the admixture of earthiness, preventing the fatty moistness from being consumed, also prevents all of the water being consumed?[278] Or is it because they are not burnt up, but rather scorched?[279]—they would actually revert to ashes. So with the water removed, for the most part a faster emergence of the oil is seen. What emerges faster does not undergo the fire's power so much, because it is not heated so much, with the result that the oil is extracted more easily and more copiously. The relevant method concerns my book *De arcanis aeternitatis*.[280]

There are also saps and woods which deliver oil without coction, and that is very effective, as in the case of the &570 turpentine tree or the mastic tree. Since the more rarefied parts are actually all that are extracted, what emerges is weak—complete powers cannot exist without substance, and we have no way of knowing when they have been completely extracted. But what is extracted by fire does not retain the pure uncorrupted powers of the thing from which extraction is done.

The best extract is the one whose substance runs out without a cooking process.[281] The most reliable is what is made by infusions. The most effective is what is made by cooking processes—I refer to a dry process, not one in water—that is to be reckoned in the next place. In fourth rank is what is extracted from almonds. In fifth and final place is an ancient process[282] which is carried out by means of cooking procedures with oil and water.[E]The distilling of waters goes on in the same way, but preserves the perfume much better if you use this technique; rose water comes out marvellously fragrant. Take a pottery vessel A,

[276] "Nola" means "little bell," which presumably alludes to the vessel's shape.

[277] A short mention of getting oil from copperas (calchantum) appeared here in 1554, but was removed for 1560.

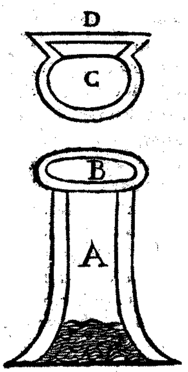
[278] Syntax obscure: "An quia terreum admistum, ut prohibet pingue humidum consumi, ita etiam aquam non totam?"

[279] "torrentur."

[280] On this work on the *Secrets of Eternity* see n. to Book I at 5 (1560).

[281] "coctio."

[282] "antiquus"—presumably "modus" is understood.



[494]stretch on top of it an open-mesh linen cloth B,[283] and scatter on it &571 roses or eyebright or other flowers or herbs. Then get a small dish C to cover the vessel, and above its mouth set a fire. A water is distilled that is not only highly perfumed but also very effective. Rose water is usually placed in a closed vessel in the sun, to lose the smell of the fume yet keep the rose perfume. The water is also made very rapidly when a glass ladle[284] is held over heated or boiling juice, and on the ladle the fume passes over into drops; the drops thus formed are assembled into water; in this way vinegar is easily turned into water. This is of use to sweep away patches and cataracts[285] on the eyes, especially if rue is cooked in white vinegar. There are people who in the first method put musk and other precious odorous substances beside F,[286] and the water retains not only its own odours, but also that of musk and the other items attached.

But why is the odour of some flowers not retained in waters, but (as in jasmine and clove flower, and lily) the water turns out odourless? It has been mentioned elsewhere that this is because no thicker part is linked to such rarefied substance. What will help in these cases is to interleave the leaves of odourless herbs with thicker matter, but not matter being burnt; let the odour be linked, then distilled. This gives the only prospect of coaxing out an odour when items infused in water do not yield the odour, but decay.

If fire is not applied with due moderation, it burns up things of an earthy nature—but if this is done with due moderation, it simply intensifies them. Therefore the Muscovites use water distilled from oats, since they have no wine—and it is as &572 warming and inebriating as wine. Oats being of rather thick substance, they must be warmed for distillation, and are thinned out and intensified,[287] and approach the nature of alcohol.[288] Hemp leaves, turned into a powder, make a pleasantly inebriating drink, because their impact is on the head. On[289] the same basis, its boiled leaves and seeds (as is said of the rather green husk of nuts), if the water is poured out on the earth, draws[290] the worms up to the earth's surface, whether it entices them by the odour or drives them forth.

283 "linteum lineum"—since "linteum" originally means "a linen cloth," there is some element of redundancy in adding the adjective "lineum."

284 "cyathus."

285 "suffusiones."

286 There is no "F" in the figure in any of the three editions.

287 "exacuatur."

288 "aqua ardens."

289 The remainder of this paragraph is not present in 1550.

290 The sentence's subject now turns singular in the Latin instead of plural.

This is why fishermen commonly use it. If hens eat the same seed, it makes them fertile in the winter—it is heating, and thinning.[291]

But I return to my theme. It is said that among the Tartars, water distilled from milk makes them drunk; so the milk ought to be rather thick, and to have spent time beside a fire. Thus this watery product is perhaps produced from mares' milk. But why hesitate further?—any water rather often distilled can produce this result; it gets warm, and rarefied, and acquires the fire's power to a greater extent. Hence alcohol distilled more often reaches such a point of pungency that it is undrinkable. So what emerges clearly from this is that wine has a fiery power, and that repeated distillation from almost anything, even the most compact, can create a drink which will warm and inebriate more than wine. The[292] reason for the drink is actually to be pleasant and potent; it delights the sense of taste by its pleasantness and the sense of smell by its strength, and it strengthens the stomach. Anything distilled turns out both delightful and perfumed—delightful because all the unpleasing part has been removed, perfumed because of the fire's power and the &573 [wrongly numbered 373] pungency of its substance. Items that are of rarefied parts have more smell; in fact the smell is that of the vapour, and vapour has its basis in rarefied substance. The same principle is found in drinks which are made without distillation, and yet are inebriating, like mead[293] for the Muscovites. It is produced from honey and hop[294] seed, and is kept in vessels sealed with pitch—although hardly any of them would be enough to produce drunkenness.

Another[295] method for a more distinguished drink, and one emitting rays like red-hot iron: four parts of zethum,[296] one of honey, a medium part of myrtle seed. They are cooked together, and the foam removed till no more forms; then six parts of zethum are added, and are kept covered for forty hours. In the common mead, instead of zethum, the same amount of water is added; the rest is as in the more distinguished drink. But in addition, instead of myrtle seeds hop seeds are added; they are cooked separately, the end point being when a not unpleasant

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[291] "attenuat."

[292] The next three sentences did not appear in 1550.

[293] "Medo"; this non-classical word is identified by Castelli as meaning "mulsum" or "aqua mulsa" or "hydromeli," all drinks created from honey with added wine or water, and it may perhaps reflect some recollection of the German word "Met," which means "mead."

[294] "lupuli," a post-classical word; the present botanical name for hops is *Humulus lupulus*. Their arrival in Europe for use in beer-making occurred before 1000 A.D. See H.S. Curran, *A History of Brewing* (Newton Abbot: David & Charles, 1975), 42–43.

[295] This paragraph is absent in 1550 and 1554.

[296] A crude beer. On the history of this from its use in ancient Egypt, and that of later forms of beer, see Curran, *History of Brewing*, and Ian S. Hornsey, *A History of Beer and Brewing* (Cambridge: Royal Society of Chemistry, 2003).

bitterness is detectable. After a number of repetitions, the odour, powers, and attractiveness are assessed by the judgment of the senses and of reason, the mistress of them.

Hop seed, along with barley or siligo wheat[297] or normal wheat, makes "zethum" or "zythum," which the Germans call "birra." The method here, as Nicolaus Pollio, the Emperor's physician,[298] left it written down, is: pour barley into water till it breaks up, then dry it, rub it finely, and place it under a grindstone. Other[299] people moisten it in heaps for three days only, and when it has started to germinate, scatter it and dry it for a further three days. Later, they spread it on linen cloths and roast it in an &574 oven.[300] Unbelievably, they say that by this method of roasting it acquires a pleasing honeyed sweetness. Take two parts of this and seven of water; they are cooked together till a third part of the water has departed. Then they take half of that water, to which they add a fortieth part of hop seed, and the same amount of barley as before; it all gets cooked for about three or four hours. Then they take the remaining middle part of the liquid, strain it, mix it with the previous liquid, and cook again till it is reduced by half. Finally they share out the discharged liquid into a wooden barrel and add a moderate amount of yeast. As the dwellers in the North have to do, they make zethum from barley and siligo wheat and normal wheat; likewise, the dwellers in the South, when the use of wine is forbidden through legal superstition,[301] make zethum from rice, and all these drinks can produce inebriation; but the one made from rice is gentler, not because rice is colder than barley, but because this sort of zethum lacks hops; hops are inordinately hot and dry, so[302] no drink's pleasure is denied; there is in fact nowhere where rice does not grow. This "wine from rice" is much more pleasant and healthy than other "zethum."[303] And the most effective is the kind that has a supply of myrtle or hop seeds. So the Dacians and Sarmatians[304] put more in. Consequently all mortals are granted wine, and in addition a doubly pleasant thing: there is honey as well everywhere.

More healthy than any zethum would be the ancient oxymel, though a little more expensive. It used to comprise thirty parts of honey, twenty-five of &575

[297] A soft variety.

[298] Not identified.

[299] The next three sentences were introduced in 1560.

[300] "clibanus."

[301] On the complex issue of the consumption of wine being forbidden in Islam, see A. J. Wensinck, *Encyclopedia of Islam*, 2nd. ed. (Leiden: Brill, 2001), under the word "Khamr."

[302] The next 4 sentences and a part of the subsequent one first appear in 1554 and are much expanded in 1560.

[303] See n. 296.

[304] Dacia lay in the loop of the lower Danube, i.e. north of it, and corresponded to Transylvania. For Sarmatia see n. to Book II at 200 (1560).

vinegar, nineteen of water, three of salt; they used to [496]add savory,[305] bring to the boil ten times, put it in a vat, and age it[306] in a vessel. Some people used to increase the water. Others operated without savory. Since, like wine, it could take in as much water through dilution, it was more healthy, and cost less.[307]

The Ethiopians—I believe because their wines do not keep, and they worship Christ[308]—moisten raisins daily with water, dry them moderately, and squeeze them out. This drink is as much better as it is less attractive. It lacks strength, and the drawbacks of wine, and— the greatest thing—the over-attractiveness generated in wine for the undoing and drunkenness of man. This makes clear that Nature has provided honey rather than wine for drinking; every region produces honey. The same honey makes a wine, for with time's help, wine is made from a preparation of honey and water. But the coldest regions do not produce grape wine, nor do the hottest ones preserve it. Wines from the remaining fruits are hard to preserve.

They are in fact made from quinces, pomegranates, pears, apples, plums, berberus, blackberries (especially wild ones), medlars, service berries, and in general from any fruit possessing a pleasant juice, healthy, and which can keep. For juice that cannot keep, cannot become wine, being incapable of being clarified—hence wine is made neither from cherry nor from peach. This is why people usually add ginger, pepper, cloves, cinnamon, macir,[309] and nutmeg. The juices that are cooked to the due point[310] keep; but while they thicken, they are no drink, not even &576 wine; so they will be grape juice boiled down into a syrup.[311] White wine from grapes turns yellow with age, because the watery portion is released. But strong dark wine stored away over many years takes on the odour and taste of alcohol, and becomes practically white, surely having less colour than a golden yellow one—the thicker part is separated, the rest is thinned out. This is the way alcohol is made. It is stored in chilled places.

I[312] have seen wine stored seventy years previously, which from twenty-five jars had shrunk to fifteen, and had turned pale from being dark; compared

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305 "thymbra," "perhaps Cretan thyme" (*OLD*), but Durling for θύμβρα gives "savory," and at his next entry gives for θύμον "Cretan thyme."

306 "inveterabantur."

307 The following three paragraphs were first introduced in 1554.

308 Presumably the relevance of their being Christian is that in Christianity there is the ceremony of the Eucharist, in which wine is drunk. In Ethiopia raisin wine is still used for this rite (http://www.ethiopianorthodoxchurch.info/BasicRequirements.html, accessed on 8 July 2011).

309 Cardano renders it as "macerem"; "macir" appears in Plin. *Nat. Hist.* 12. 32, which refers to the reddish skin of a large root of a tree of that name, and *OLD* defines it as "the fragrant resin of *Ailantus malabarica*." This sentence is not present in 1554.

310 "meta."

311 "defruta" (*OLD).*

312 The following three sentences appear first in 1560.

to alcohol, it was as much more pleasant as it was weaker. It is useful for ill-digested[313] humours and for cold and moist diseases. I hear that the Senate at Lübeck[314] boasts that it can keep Rhine wines for two hundred years in store-rooms. Long ago at Falernum,[315] later at Sorrento,[316] afterwards at Sezza,[317] the price was very high, because otherwise distinguished and notable wines were being stored for many years. Dark wines also pass over into white ones, losing their taste and odour, on straining through Indian stone;[318] the thicker and darker part is held back in the stone, and what passes through is altered from its outstanding coldness. So Indian stone should be a kind of marble.

There are other pleasant inebriating drinks, such as Mignol at Senega, which extends a little towards the Equator beyond the Canaries.[319] This juice is not unlike the whey of milk in substance and colour, apart from tending towards the ashy colour of an injured tree. Another more notable juice is extracted from a berry (it is a kind of palm). This tree grows plentifully in Chimam, a province of the coast of &577 Surenum, tall, with the leaves of a palm tree, and a fruit larger than a man's head. This fruit is covered with membranes and tow from its topmost surface to its middle. From its thicker part ropes are woven, and from its thinner part garments. Around its middle is a shell like a walnut's, and under it a thin white kernel, with a taste, substance, and nature like fresh almonds. Further, the kernel when freshly crushed releases a milk just as sweet as animal milk. In the centre of this kernel a juice is contained comparable in attractiveness to no other drink. Again, since the shell that surrounds the kernel glitters and is dark and hard, cups are made from it that are very delightful to use. The Italians call this fruit the "Indian nut." It is on sale with us as a whole item.[320]

But now that we have got round to mentioning the berry, this will be the time to discuss it, since there is no tree offering so many uses. India produces it, which is thought to occur in the month of August, and in the meantime a glossy white sap flows out, as is usual too from the so-called vines, and the sap

313 "crudus."

314 "Lubicensis."

315 A district north of Campania in Italy, celebrated for its wine.

316 Southwest of Naples, in Italy.

317 "Setia," in Latium near Rome.

318 "The magnet (*magnes*) is a stone of India, named after its discoverer, for it was first found in India, clinging to the nails of his sandals and the point of his staff, when a certain Magnes was grazing his herds" (Isidore, *Etymologiae*, 16; trans. Barney et al., 319), but Cardano does not seem to adopt this identification; just below, he calls Indian stone "a kind of marble."

319 On the "Fortunatae Insulae" see n. to Book II at 200 (1560). "Senega" is Senegal, at the furthest western tip of the continent of Africa, and some 1600 km to the south of the Canaries. The Equator is some 1600 km further south still.

320 "integer." The nut here is evidently a sort of coconut. The first of the two preceding sentences was introduced first in 1554, and the second in 1560.

resembles wine[321] for the whole of three days. But if you cook this till the third day, it turns into an utterly delightful honey. However, if it is not cooked nor drunk, it turns into vinegar. Further, if the honey is freed of water, in the course of twenty days it turns into wine.

From the fruit's stones an oil is expressed. And they are eaten in lieu of walnuts or almonds. From the outer shell charcoal is made, while clothing is spun from the inner bark,[322] even more delicate than cotton, almost as good as silk. They use the leaves to roof their houses, instead of tiles. And so although all the kinds of palms have many uses, the berry is the &578 most notable. The palm has very long leaves, spiny and green ones, and curved because of their length, and gathered together at the top like a mane. The bark is soft and has very large scales, riding one on top of another, all unequal, like those of fishes with a back covered with scales. I saw one like this in the temple of Peace at Genoa, but not bearing fruit. Some transplanted trees do not survive, like the aloe wood moved to Italy from India; some do, but bear no fruit, like the palm at Genoa; some bear fruit, but impaired fruit, like pepper with us; and some are tolerant of both climates, and bear perfect fruit, like the vines transferred to India from Spain. The topmost part of a palm's trunk is soft where the leaves and branches unite in a raised ridge,[323] and when cut off is not only chewed but regarded as a treat; but it lacks taste and is rather bitter. All of the wood has fleshy substance, but only at that part is it soft enough to eat, more than any other young tree. It is young for a long time, because anyone who sows a palm tree hardly ever sees the fruit, it starts bearing so late. And[324] this plant appears to exhibit a large semblance[325] of the power of sensation; in Data, a town in Numidia,[326] where it is plentiful, if a bough of a male flowering[327] is not mingled with boughs of a female one, the fruits develop stunted, nasty-tasting and with too big a stone. And if it receives no assistance from the male, the fruits tend to fall.[328] However, if its ash or leaves or bark are reinforced, it brings fruit to ripeness. It is no wonder that what is

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[321] "vinum"—and classically this word can also mean "grapes," which may be intended here.

[322] "liber"—the same word also means "book."

[323] "torus."

[324] The remainder of this paragraph was first introduced in 1554.

[325] "species."

[326] The northern part of modern Algeria, from about 100 miles west of Oran to the border of Tunis.

[327] "specimen."

[328] On Cardano's recognition (derived from Theophrastus) that sexual reproduction is not entirely unknown in plants, see n. 42 above.

nourished by similar things is &579 strengthened by them. It is therefore [496] better to join Plato in thinking that plants possess a sort of sensation.[329]

The shoots[330] produce the same taste, and have the same fleshy white solid substance, but their bottom, linked to the root, is the only part that is chewed. The twigs, which resemble the palm's leaves, are white too, but woody, and unsuitable for food. The taste is the same as that of the top of the palm's trunk, which is therefore usually eaten with salt, pepper and oil.

But the shoots differ greatly from the palm; in the way that a tall palm is a tree and bears dates, the shoots bear clusters[331] like grape bunches; the other palms are similar. But[332] this palm is superior in one feature: it arouses sexual appetite[333] marvellously, and more strongly than all other love-potions; there is much waste in the third concoction, and it leads to a lot of flatus, and is very stimulating, and lingers long in the stomach.

Sicily abounds in this bush, from which bdelium[334] also is extracted, but darkish and less effective; however, it does have the power of a pleasing odour. The best was at one time highly prized, so that in Genesis Moses ranked it among the special items, linking it with gold—either just for the excellence of the sap, or for the usefulness of the plant too.[335] Evidently he felt that such an exceptional plant, and one with a fruit from which a choice incense poured out, should be placed among a garden of delights. But it seems that Moses had another kind of plant in mind, and the Bactrian district; &580 in fact there bdelium arises from a tree, not a bush—one that has the size of an olive tree, and the dark leaf of an oak tree, and the fruit of a wild fig; it is from that that I affirm bdelium arises, rather than from a palm shoot.[336] For what Moses praises is of an outstanding fragrance—ours smells bad, still less can it be reckoned with the incenses.

But palm shoots do occur on dry twigs, and similarly some other herbs with quite fatty leaves, such as aloe and house-leek, and the Indian tree with quite a big leaf, yet one not so fatty as that of the aloe, but remarkably prickly on the back, though the prickles are small. So as fatty plants contain a lot of humour,

[329] Plato (*Timaeus* 77b) wrote that plants partake of "sensation, pleasant and painful, together with desires."

[330] "palmites"—or may this be another sort of palm tree?—however, the word is *plural,* the plural of "palmes."

[331] "racemos."

[332] The remainder of this paragraph and the next one were first introduced in 1554.

[333] "venerem."

[334] Bdellium, Greek βδέλλι•ν, an aromatic gum (Celsus 5. 5. 2). Cardano spells it with one L, not 2.

[335] The reference is to the Bible, Genesis 2: 12: "And the gold of that land (Havilah) is good; there is bdellium and the onyx stone." Bdellium is mentioned also in Numbers 11: 7: "And the manna was as coriander seed, and the colour thereof as the colour of bdellium."

[336] "palmite."

accordingly the prickly vegetables (such as all the kinds of thistle) call forth urine, because fiery moistness has to be plentiful in them.

But since aloe is very bitter, why does it have very fatty leaves? –it is very similar to house-leek, but blackish, and the size of a cubit,[337] as I have often seen. The reason is that as it is prickly at the tip of the leaves, there has to be abundance of heat and dryness in such copious moistness, to be capable of making the spines; hence as they project little in comparison to the size of the leaves, the moistness inside needs to be burnt out, and the juice needs to be made very bitter.

But I return to the trees—especially the uncommon ones from which the so-called "holy wood"[338] is obtained, wood which is imported from the islands of the West Indies, from which the Disease[339] too crept in. And although we have published eight books on the nature of this disease,[340] I have resolved to describe the form of the tree here. &581 It is grown in Spain and around the nearby islands of the New World, a little smaller than a walnut, with a patchy bark alternating between green and ashy, a leaf smaller and greener than a wild strawberry.[341] The flower is shiny-white, the fruit saffron yellow, its shape and size similar to two wild lupins linked together. The tree is so widespread that groves are seen everywhere, like oak woods with us. We extract from it (and not only from it, but also from any other tree) a sap which is more costly than the actual wood, in this manner: the wood is cut into slices as thick as a finger, and they are exposed to fire, then any of the sap there is in the wood is collected. There[342] are two kinds of sap: the liquid and the dry—and also the raw, such as that of the cherry and plum, and the fatty, such as that of all pine trees (it does burn).[343] Why the latter burn and the former do not has been explained previously. But it has not been explained yet why the latter turn liquid and others remain dry. They liquefy because they contain little of earthiness; the edges, which have most earth, do not liquefy. So the sap from pine trees is more concocted, and better suited for maturing—but not hotter, for the sap from Euphorbium[344] is the hottest, although it belongs to the kind of milk, not that of pine trees.

Euphorbium is also the milk of a thorny plant, but one not outstandingly shiny white, and because it dries up over time, like the sap of the mastic tree, it also yellows the teeth, which is a sign of its age. A similar thing occurs with

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[337] The distance from the elbow to the finger tips, i.e. about 45 cm.

[338] "lignum sanctum," also known as "lignum vitae" and "guaiacum." See n. 102 above.

[339] Syphilis.

[340] *De morbo Gallico*, composed in 1537–1539; for further detail see Maclean, *De libris propriis*, M42 [67–68].

[341] "arbutus."

[342] The remainder of this paragraph and the five following paragraphs were first introduced in 1554.

[343] Torches were made from pine wood.

[344] Spurge.

the bahara root[345] while it is being gathered: the juice is sharp,[346] also because all the so-called milk arises from either the decay or the coldness or the dryness of plants.

But since this juice is not precisely &582 shiny white, but yellowish, it does not arise from coldness. We shall make clear later that every spiny plant is excessively dry; so spurge is excessively dry. But it is very hot, and for this reason, if placed for a day on top of bare bones, it can remove the surface from them, such is its power. In the same way, milk of tithymal[347] shatters teeth.

But you will say: since there are only four moist things in mixtures, to what kind will sap be assigned? Sap is on trees what mucous juice is on herbs—the latter is hardly present in plants, while sap is uncommon in herbs. Mucous juice is imperfect in relation to the fat of oil, but sap has fatty moistness mixed with wateriness and earthiness. There is thus oil in every sap, and thus it is easy to extract. Saps are dry, like styrax[348] and Greek pitch, and pitch for ships. These are extracted from slices of pine tree put into a furnace, to burn for some time; what is called the pitch for ships distils black and clear, it takes up oil, and is cleaned by it. Sap is scoured by oil, and the oil by bran. Containers coated with pitch absorb oil if it is placed in them, on account of their dryness combined with rarefaction. And since every gum[349] is fat and of watery substance, clearly too it all is transparent, even where it is plentiful.

Hence if houses are made of thin larch planks, [497]the planks glow so much when lights are placed on them that they seem wholly on fire. Larch wood is in fact reddish and &583 translucent; this made it easy for barbarians and people long ago[350] to impress common people with these tricks;[351] now it is enough to use them for stage scenery.[352]

Greek pitch is made from a spruce tree's sap, and what is called colophony, suitable for plectra. The pine tree's sap when raw is colophony, and after heating is Greek pitch; what is sweated out of the wood during heating in furnaces is pitch for ships. All that remains is for us to explain how all fat is translucent moistness. It is like this because in it the heavenly heat is flourishing, and from it comes the concocting. The heavenly heat brings clearness, like what exists from the Sun,

345 Not identified.

346 "acris enim succus," but "succus" being masculine, "acris" feminine, the two cannot normally agree to mean "an acid juice." An alternative is to suppose that "succus ac*e*ris" is meant: the juice of a maple tree. Syntax and meaning obscure.

347 Another kind of spurge.

348 An aromatic gum derived from the tree *Styrax officinalis.*

349 "gummi."

350 "antiquis."

351 "experimentis."

352 "ad scenas"; might alternatively mean "for platforms."

the Moon, the stars, and their illumination. So if a great deal of earth is mixed in, it glitters; if little, it both glitters and shines and is translucent.

But enough on these topics; back to our plan. There is a fruit, of which in those regions they call the hollow stalk[353] "Cassia"; it has a smooth pod, rust-coloured or black, the size of a thumb, sometimes longer than a cubit,[354] set at an angle, with a very sweet but unpleasing juice, small stones like lupins but much harder; the tree tall,[355] with the leaf of a nut tree, but narrower and thinner; the flower tawny, very like broom, intolerant of cold, very eager for moistness,[356] so that it extends its roots right into underlying water. This prevents its being generated in our regions, because from the start the weather's inclemency impedes it, and as it grows moistness is lacking; in our regions, the waters[357] lie rather deep.

There are also remarkable powers of trees extending from their shadow; destructive ones in "toxicus,"[358] walnut, spurge, the &584 full-grown fig, the Indian service-tree,[359] aconite, yew, oleander—this tree is supposed with us to bear frequent fruit, like dark cassia[360] but not almond—the stalk is full of knots. Dioscorides overlooked this and was deceived about the fruit, with the result that I would not regard the tree we have as oleander, but as dark cassia, because of the fruit's resemblance. However, it is not accepted as cassia, but since with its leaf and flower it is deadly to beasts of burden, sheep, goats, and pigs, I would like to hear the view of those who are so curious about details. It is harmful to human beings, though not deadly.

Wholesome fruits are on the lotus, beech, and Indian hobium.[361] Some are of use on account of their perfume, such as the rose, myrtle, nard, citron, juniper, just as there is harm in boxwood. And among these brasilium has entered the contest through the diversity of its colours—some people call it "verzinum."[362] The province is Brasilia, so named from the groves which are made up of this

[353] Also known as the "quill."

[354] See n. 337 above.

[355] The 1560 ed. greatly alters the remainder of this paragraph, replacing a description in the 1554 ed. of a personal inspection of this plant.

[356] "humor."

[357] "latices": can mean waters, running waters, or liquids (*OLD*).

[358] A variety of the shrub *Cistus* called "ladanum" which exudes a gum (Plin. *Nat. Hist.* 26. 47).

[359] The rest of this paragraph was first introduced in 1560.

[360] Reading "cassiae" instead of the "cassis" of 1560.

[361] Or "hobius"; not identified.

[362] Brasilium is a tree native to the *East* Indies, with wood carrying a reddish tinge useful in dyeing, and is a word cognate with French brésil, Old French berzi, Old Italian verzino, Medieval Latin brezellum, brasilium, bresillum, braxile. The country Brazil, when subsequently discovered, contained similar trees and thus acquired its name. For further detail see *OED*.

wood, the tree not big, like Enzina,[363] but thinner and set more at an angle. Leaf like an oak's, but not rough. The bark falls off the tree rather of itself, through dryness.

But as we have mentioned that it is like the Enzina, the Enzina oak tree is a king in Spain, smaller and not so straight; its acorns are eaten because of their sweetness. With age brasilium grows better, and reddens more, and in this differs from fake brasilium. It is light, sweetish, and of an astringent taste. It has notable strength for dyeing and for writing, and this red ink is prepared in many ways. Some people put its dust scraped off with glass into a strong and still boiling lye.[364] An eighth part of the wood &585 is enough, with a moderate addition of alum among the hot cinders, and it is cooked for an hour, and put into use at once, and no Arabian sap is required. I have been in the habit of making it another way: the wood is drawn out into very thin threads, and I cut it into little slices, and put them into ten times as much water by weight, and leave soaking to go on for at least six hours. Then the water is boiled away with the wood till three quarters are lost, and the colour gets ruddy and shining. If you boil it down a little longer, it gets blood red—if still longer, blue. Prepared by either method, unless put to use at once, it cannot be kept long. It is characteristic of all the colours which come into being from the parts of plants to change with time, and not to be pure at all, because the matter of plants is weak and full of humour. Thus from one and the same plant all the Indian colours are extracted by heating for a longer or shorter time.

A surer and more lively red colour is the one made from cinnabar;[365] it is dissolved in water tinted with Arabian sap, or in white of egg brought to the appearance of water after long shaking. But in this lies its shortcoming: if you mix in a great deal of humour, when the cinnabar settles down the colour turns more dilute; if just a little, it is removed very quickly, because cinnabar is excessively drying.

In the list of kinds of tree that are outstanding in the diversity of their colours, the origin is the elm, and next comes the olive. This is why from these come vessels and planks most attractive in use, not just because of the colour but also because of the bright appearance. The reason for the diversity of colours is the diversity of heat, and the olive portion. As in the case of clothing, so in these cases oil alters the original colours &586 [wrongly numbered 558] while spoiling them. But what is spoken of as a blemish in clothing is welcome variety in these, because of being combined with glitter.

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[363] Evidently a word for the holm-oak tree, *Quercus ilex*; see next paragraph.

[364] Reading " . . . scobem immittunt derasum vitro: sufficit ligni pars octava . . ." instead of "scobem immittunt: derasum vitro sufficit ligni pars octava . . ." of 1560; "scobis" as masculine is reported from Vitruvius by *OLD*.

[365] See n. to Book II at 137 (1560).

The[366] top esteem would be accorded to the birch tree, if it were as common with us as with the Getae[367] and the Sarmatians.[368] It has pictures on its roots, of plants, birds, quadrupeds — the tree itself is midway (so to speak) between the poplar and the pine, and bears small tendrils[369] like hazel nuts, and a fruit, from which they make bread. Below the bark there is a pleasant liquid which relieves thirst. Houses are roofed with the bark.[370] Switches from this tree are resistant, so that the Roman lictors used them for flogging. And the actual wood does not easily shatter, so it is a material for shields. It is remarkably white, and a wood that permits splitting into very thin pieces as planks. Country folk use the sticks for tying things, the substance is so flexible. It thrives[371] in the coldest places, and is hospitable to snakes, of which a large supply can very often be regularly found in the roots.

The juice of a lemon draws its colour to favourable notice by changing it in the skins in an alternating variation; while it spoils the earlier one, by retaining the glint it is said to make the colour varied and not patchy.[372] The roots of bamboo[373] too are attractive from the diversity of their colouring and from their glint. And in all these features it is the trees growing on the mountains that stand out rather than those in lower situations.

The wood of the yew tree[374] [498]is reckoned among the beautiful woods, the one from which bows are made. There is a bright rosy colour in it. But the trunk of the ash is the most beautiful of all; it is cut into thin sheets, planks are made of these, and tables of &587 high value.[375] It has a native beauty, consisting in the subtle diversity of its waves, and when flax seed oil is smeared on, these waves are enhanced so much as to look golden. The waves will absorb it because of their heat and rarefaction, and the subtlety of the oil's substance. By this absorption a brightness and colour are added which is not transient but permanent; every oil, as I have said, does shine, but this one especially, so that it makes other woods too more beautiful.

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366 The next paragraph was introduced in 1560.

367 A Thracian tribe on the lower Danube.

368 Another tribe associated with a similar neighbourhood.

369 "capreolos"; *OLD* offers no other meaning except "roe deer" or "rafter."

370 Some of them still are, in Norway.

371 "gaudet."

372 Obscure: "Sic succus limunii colorem in coriis alterna varietate mutans commendat: nam priorem dum vitiat, retento nitore, varium dicitur reddere, non maculosum."

373 "cannae Indicae."

374 The next five paragraphs first appeared in 1554. The word here in both 1554 and 1560 is "Naxos," here and just below, not identifiable as a tree. But bows, at least in England, are made from yew, in Latin "taxus." So I have read "taxus" here.

375 "preciosi usus."

The ash tree is selected from Germany, as the yew tree is from Medera, an island of the West. But while these produce very beautiful timber, the most beautiful of trees is the plane tree. Once upon a time it earned the affection of Xerxes, King of Kings.[376] To start with, he admired it. Then he fell so in love with it that while setting out on his expedition he spent a whole day under it; then he departed and left guards and gifts for his beloved. He actually attached bracelets, collars, cloaks, and the other regalia of nobility to its branches, to testify to his love.

Perhaps you will enquire about the source of such beauty in plants. It is agreed to come from a thick and evergreeen verdure, strong spreading branches, healthy and plentiful shade, a rounded trunk, thick and firm, with deep roots watered all the time by a clear spring; there is a flourishing appearance of greenness, and winds that busily shake the tree. These, I say, are the features that could attract a very great King to love it.

Hence the second place of honour for beauty is due to the lotus tree. It is not so common in Italy, but does &588 appear there, in that celebrated parent of all good things and all bad ones alike. The lotus is a tall tree, spreading, with a smooth blue bark, the fruit of a small cherry tree, sweet and perfumed. The tree has a charm so great as to extend even to its name; there is a herb of the same name, about which the Poets tell a tale that those who have eaten it are smitten by such delight that they are unable to leave the place where it is profuse.[377] But this is no place for tales; a serious account[378] is to be worked through.

And so we said that plants receive all the colours, but not all the tastes—they are thought to lack the salty one. They have the others: bitter, sweet, pungent, acid. Bitter are gentian, aloes, santonicum (the kind of wormwood).[379] Sweet are liquorice, sugar, polypodium.[380] Pungent are pepperwort,[381] pepper, nasturtium, garlics, onions. Acid are such as wild sorrel,[382] oxylapathum.[383] Tasteless are turnip, mallow, beet. But Theophrastus thinks none are of a salty taste, although moss is salty, but not much. He says the reason for this is that the nutrition of plants cannot be salty in any way. But as there are many salty earths, yet the herbs that grow at the seaside are not salty, it cannot be supposed that the reason is lack of salty nutrition. So what we say is that a number of plants are salty, but not so

[376] Herodotus, *Histories*, 7. 31. 1: "Xerxes went by this road and found a plane-tree, which he adorned with gold because of its beauty, and he assigned one of his immortals to guard it" (trans. Godley).

[377] Homer. *Odyssey*, 9. 82–104.

[378] "historia."

[379] See n. 26 above.

[380] A kind of fern (*OLD*).

[381] "siliquastrum"; see n. 71 above.

[382] "oxalis."

[383] "a kind of dock" (*OLD*).

many as are bitter or sweet, nor so obviously so. Since a salty taste is the only one to corrode, but plants slowly emit their waste matter, it is hardly possible for a plant to be notably salty; it is in fact moist, and moist things corrode a salty one, as we have also &589 seen in the case of animals, which are only corroded and eaten away by a humour preferring this taste. Since some plants (such as Seville oranges, lemons, oranges) are not strongly tolerant of salty earth, if they are not frequently watered they dry up on the spot, since the saltiness does not moderate, and kills off the plant at once. Furthermore, since all tastes apart from the salty one can exist in rarefied substance, in the case of a plant attracting rarefied nutriment only, it will also be able to attract all tastes except the salty one. Again, saltiness is the weakest of the tastes; a lot of salt is needed to make water salt. So as what is salty does little nourishing, and is attracted with difficulty, because it is thick and does much harm, and works little on the sense of taste, there must be few salty plants, and those that are like that appear thinly salty. However, the Indian sea nourishes a salty herb which is called salgazum,[384] which is always floating on its surface, and is so plentiful that it resembles flowery meadows; it is partly green and partly yellow, and is not nourished by saltiness, but (as I said) by fatty moistness, which is linked with salt. Our own sea too supports a very soft kind of herb called alga, which is nourished from fattiness on the same basis, leaving the saltiness behind, so that it sprouts in spring, and flourishes in summer, and dies off in winter. Also, because it is nourished from fattiness, it is well suited for transport of pitchers, so that the Venetians transport glass vessels to us buried in it. Coralina[385] too, a kind of sea moss, is notably salty, but only on its outer surface; &590 so when it has been chewed, at the end only the astringent taste remains. It is a herb with a thin stem and tiny leaf; the best is scarlet or purple, and shining. It gives great protection against worms, especially taken with milk. And so the salty taste adheres to it rather than being implanted.

But where do plants in water come from? Aristotle says, and rightly, that when the water is at rest, the topmost part is corrupted by the air's heat, and rots, and in this way acquires life. But because the water happens to be in motion, a herb without leaves and a root is generated.[386] The evidence that normal herbs are

[384] 1550 calls it "salgazum mobile." There may be a connection with sargassum (derived from Portuguese "sargaço"), a variety of seaweed which has given its name to a calm portion of the Atlantic Ocean where it is abundant—the Sargasso Sea. See John Murray, *Selections from Report on the Scientific Results of the Voyage of HMS Challenger during the years 1872–76* (Edinburgh: HMSO, 1977), 4, n.3.

[385] The rest of this paragraph was introduced in 1560. Subsequent material to [F] on 591 (1560) was introduced in 1554.

[386] Aristotle (*De plantis*, 2. 4; 825a40–b8; Loeb 205) says: "Plants which grow on the surface of the water only do so because of the density of the water. For when heat touches the water, which on the surface is incapable of movement, something like a cloud comes over it, and it retains a little air, the moisture grows impure, and the heat draws

generated because of stillness[387] is that in rivers the water flows all the time, and no herb is generated. So when you see a herb growing in water, it will show you that those waters are at rest and are decaying.

To continue: because a leafless herb cannot exist on water, and we said that this one lacked leaves, the plant itself will be like sown leaves. To lack leaves indicates that these are herbs that come into being on the waters. Rushes lack foliage, although not growing on water, but on the channels and banks of watercourses. Waves would compel them to drop off foliage or leaves, if there were any.

[499]On a similar basis they are flexible, as Dante in the Purgatorio[388] elegantly explains, and so are any other plants exposed to waves in water, such as bamboos; they would be broken or killed off by the waves, if they were not flexible.

For every kind of rushes and bamboos it was important to be hollow; a thick thing cannot bend &591 unless it is. But imagine thick, solid yet flexible bamboos: will they get twisted spontaneously because of their own weight?[389] To make them capable of being straight, they are made large, empty, and hard. The tasteful walking sticks of the elderly are made from these and from wooden rods.[390] But some Indian bamboos seem to be knot-free, possibly a different kind—certainly hollow and very light. There they grow to an incredible size—middling soft while alive, hard while they are drying. They are nourished by fatty, not salty, moistness. [F] This is why the Indian soil is to be regarded as very fatty and minimally salty, because trees grow to a huge size there. People actually say that some tree was found there belonging to the Ceiba kind (this is the kind of the largest tree of all) divided into three trunks among the rest of the trees, and each of its trunks had a circumference of twenty feet. The gaps between the trunks close to the ground were of the same number of feet; and through the gaps a laden wagon could be prettily driven. But where the trunks were uniting into one, at about fifteen feet from the ground, the thickness of the tree in feet was forty five. From the bottom of the thicker trunk to the point where branches were first being given off was eighty feet. There was no means of measuring the upper part, from which the branches were hanging. The cause of this vast height was favourable soil, sturdy climate, and the tree's nature; its wood is very light,

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it up; this spreads over the face of the water, and so the plant grows. But it has no root, because a root is fixed in the parts of the earth, and has its parts distinct. A plant of this kind has no leaves . . ."

387 "quies."

388 Dante, *Purgatorio*, Canto I, 100–105 (trans. Sayers): "All round this little island, on the strand, / Far down below there, where the breakers strive, / Grow the tall rushes from the oozy sand; / No other plant could keep itself alive: / None that bears leaf, or hardens in its prime / And will not bend when wind and water drive."

389 "gravitas."

390 "ferulis"; it is not easy to distinguish these from the reeds.

possessing a moderate amount of earth and of a more rarefied sort, and a great deal of moistness.

As a rule great trees are supported by deeper roots, with the result that where the district is dry, the &592 root makes its way down for three cubits[391] or as much as four. And trees made of more solid matter cannot grow huge, as occurs in the island Hispaniola[392] of the New World. And in the mountains there at that time, where the trees do not send roots down to the bottom of the earth, the people are treacherous and unreliable, because either the excessive dryness or the constant changing of the winds renders the characters of mortals changeable and irresponsible, and hence treacherous and unreliable. People in fact generally follow the nature of their climate.

The trees that fail to send down deep roots because the soil is dry cannot survive long. Of itself, indeed, the nature of trees is prolonged to an immense age. Josephus recounts that an oak of Abraham's was still there in his own time; the interval between the destruction of Jerusalem[393] and Abraham's dream[394] is exactly two thousand years.

After the oak come the palm, the plane tree, the beech, the olive, the pine, the elm. Theophrastus feels otherwise; but the facts are more credible than the whimsies of the Greeks. The size of trees and the spread of their roots shows that their old age is long. The cause of longer life is scantiness of fruit, and (to put it that way) sterility—and then the wood's solid substance. Thus oak wood stays indefinitely intact under water, merely blackening. Since it is solid, it is not corrupted by water, nor easily destroyed so long as it is alive.

On a contrary basis, the tree which bears the fruits of paradise has a very brief life; the trunk dries up in the second year; it bears fruits in bunches[395] &593 like the grapes of a bunch, but as big as an apple, and sometimes there are a hundred in one bunch, so that the bunch reproduces the size of a chest.[396] It is enclosed in a yellow covering, and when this is removed a very sweet and pleasing fruit lies below. It bears a leaf so long that it equals a man standing, and is quite wide too. Thus it gets exhausted by the numerous fruits and the large leaves. Hence there are almost no trees with sizeable leaves of considerable age, but they

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391 See n. 337 above.

392 1560 reads "Hispania" here, but surely Hispaniola, the island in the West Indies, is meant; on this see n. at 127 (1560) in Book II..

393 Jerusalem was razed in A.D. 70 by Titus the son of the Roman Emperor Vespasian.

394 The reference is to the oak of Mamre, site of the Hospitality of Abraham (Genesis 18: 1–19), still shown in late antiquity and in the Middle Ages. See G. Vikan et al., "Mamre, Oak of," *Oxford Dictionary of Byzantium* 2: 1279–80; the site of the oak was masked by a Constantinian basilica.

395 "botris," which is late Latin for "grapes" but surely means "bunches" here.

396 "cista."

are found on herbs, cabbage, sorrel, gourd. And height is no help to this last one the gourd, since it dies in the same year as its birth; big leaves need liberal moistness; since this is abundant yet not fatty, it leads rapidly to death. This is why wild plants live longer than cultivated ones, and earth-born things than those born in waters. These causes make the laurel with its spongy wood, the pomegranate, also the fig and the fruits it bears, short-lived; they all burgeon with fruit too much for the size of the tree.

Among the fruit-bearing trees let me not pass over the vine in silence—which sometimes bears fruit thrice in a year, so that it is called "trifer," but the final bunch does not ripen. With the fig it is well known that it bears fruit twice in the same year, the first sparser and larger, and the second more crowded and correspondingly smaller. It is obvious that apart from the fig, every tree flowers as often as it is in process of bearing fruit.

There are also trees like ivy which cling to other trees, and others like mistletoe that grow on other trees—when its seed is eaten by a magpie[397] or &594 thrush, it is not digested, but as it falls on the tree mixed with dung, heat, and moistness, it generates roots. It obtains three benefits from the tree: since it has more dung, no great amount can be gathered in the earth; thanks to the branches covering it, it is not readily damaged by rain or Sun; and it is not thinned out by the humour of the soil. So it is markedly compact,[398] because it is not concocted in the birds' stomachs, and needs little moistness and much heat. It grows best on fir, oak, and pine;[399] it is evergreen, even on deciduous trees—it actually seems to have a family-founding[400] power. Aristotle reports that the herb lincostis[401] was very spiny, so as to give birth to another one from itself, on this basis. For since it was appearing in water, and was spiny, it used to gather much humour between its spines, which with the passage of time rotted and would produce another kind of herb, from the Sun's heat. So it is clear how and why a plant grows on another plant. A point worth questioning is whether what grows is always the same; it appears in fact that a herb that grows on another one is limited to fixed kinds. Not every plant can grow thus; mostly it is the same one, not always. And all the plants that grow on other ones [500]seem to possess something of a more note-

[397] "pica"; can also mean "jay."

[398] "densum."

[399] Text from here to [G] on 601 (1560) appears first in 1554, but the rest of the current sentence (only) was introduced in 1560.

[400] γενάρχι●ν—this word is not included in any dictionary consulted, but γεναρχέω and γενάρχης are, and both words concern being "ancestor of a family or of the human race."

[401] This passage occurs first in 1554. The word "lincostis" there and in 1560 should I think read "linozostis," a word used by Aristotle (*De Plantis*, 6.827a2; Loeb [*Aristotle: Minor Works*], 215) when discussing behaviour of plants with many thorns. "Thence arises the herb known as mercury (λινόζωστις) and similar plants."

worthy nature and to excel in their powers; nature regularly makes things that depend[402] on others more noteworthy—the end point has a basis, which comes into being in another and from another. Things that quickly die (like teasel,[403] though it contains water and dew) generate nothing else.

Incidentally, it is a general feature that &595 [erroneously numbered 593] plants grow on all trees when the bark gapes open or splits, or fails through old age, or when in some way or other some juice or water gathers because of a level surface, along with earth. I mention juice, because very often they are nourished from the plant's own moistness, as ivy is—hence the remark that creeping ivy kills off the tree's powers, the Comic author meaning that a plant attached to its mother will be destructive.[404] So their origins determine the kinds of plants in a fixed fashion, yet not always nor precisely—the cypress being an extremely large tree, it nevertheless originated in Crete, either spontaneously or from a tiny seed—and therefore could appear a threefold miracle, if we had not explained earlier that the same thing comes into being in plants both spontaneously and from seed. But I do not really know what could be more remarkable than for such a huge tree to be born from seed, or without seed. It is an extremely dry tree, with very fatty and greatly concocted moistness; hence it loathes dung and manure, and gets dry beside waters. Its wood is odorous, and does not lose the odour with age. It is not chewed by moths nor otherwise corrupted. Furthermore, when its leaves are bruised on clothing, or mixed with cereal seeds, it can prevent all damage from these creatures, such as moths and cockroaches. It is extraordinary that its seed should be beloved of ants. This wood also gives off a sap—and as is to be expected, an acrid one. So the principles[405] of plants do not alter their species,[406] but instead increase or reduce their size, form, and powers. Plants have two principles: the location and the soil. And that is why different ones come up in different places or different soil—just as a berry used to come up long ago where the inhabitants of Ambrossus are in Phocis,[407] with which even now &596 our purple is tinted. It is a bush (as Pausanias, a truthful man, reports)

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[402] "indigent."

[403] "Veneris labrum."

[404] "unde etiam illud, ut hedera serpens vires arboreas necat, Comico significante, Adnatam plantam matri fore perniciosam." The words "ut hedera serpens vires arboreas necat," are included in line 122 of a Fragment of an otherwise unidentified work by the Roman comic writer Decimus Laberius (c. 115–43 B.C.) who composed popular pieces called *Mimi*, but of whom little is otherwise known. (See Ribbeck, ed., *Scaenicae romanorum poesis fragmenta*, vol. 2, *Comicorum Fragmenta*, 297).

[405] "principia."

[406] "species."

[407] A small region in central mainland Greece, celebrated for containing the oracle of Apollo at Delphi.

of the size of a "rhamnos,"[408] like a rush, but with softer and darker leaves. The fruit is like nightshade's, the size of vetch.[409] When it is ripe too soon, a creature is born from it like a midge, but smaller, which flies off—so it is usually harvested before the creature bursts out.[410] Berberis grows profusely on a similar basis in the plains of France, especially in the province of Lyons; and the box tree in the mountains; France, as is usually said, especially that part of it, is rocky and windy and aggressive.[411] So box thrives in stony soil, in a slightly chilly climate, and delights in winds. The maritime pine[412] usually grows in the colder valleys and mountains. On a contrary basis, on the island St Thomas, which lies under the equatorial circle,[413] corn changes over into a herb, because of the temperament of the soil and climate, and frustrates the farmers. The same thing occurs in our own regions, since the downpours are too plentiful. And on the same basis, the vines alter the bunches of grapes into vine tendrils[414] because of the excessive rains. Then when a change of climate is ruled out, the soil may change. This will occur if the fields grow fat with a particular ash, or with earth dug out, or with dung. All rivers nourish special herbs or trees; similarly, rotting matters or ashes are matched one to another. As a rule, however, all plants delight in their own shreds, since during the corruption of the matter, it retains something of its earlier nature, and therefore remains the same. But transmutation and nutrition are better and easier from like things.

The cherry delights greatly in this resemblance. And this plan is suited not just to plants, but to most &597 animals that have their origin from putrid matter. Hence the ash of worms retains a fragment[415] of worms, and generates other worms, and the refuse of scorpions generates scorpions, and in general alike things are generated from the decay of their own kind, as we have explained

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[408] This is the name of several thorny shrubs (*OLD*).

[409] "eruum."

[410] Pausanias (*Description of Greece*, 10. 36. 1; Loeb 4: 585–87): "and in the territory of Ambrossus grow shrubs, though not close together like the vines. This shrub the Ionians, as well as the rest of the Greeks, call kokkos, and the Gauls above Phrygia call it in their native speech hys. This kokkos grows to the size of what is called the rhamnos; the leaves are darker and softer than those of the mastich-tree, though in other respects the two are alike. Its fruit is like the fruit of the nightshade, and its size is about that of the bitter vetch. There breeds in the fruit of the kokkos a small creature. If this should reach the air when the fruit has ripened, it becomes in appearance like a gnat, and immediately flies away. But as it is, they gather the fruit of the kokkos before the creature begins to move, and the blood of the creature serves as a dye for wool."

[411] "rixosa."

[412] "pinaster."

[413] St Thomas in the Virgin Islands is about 18^0 north of the Equator.

[414] "capreolos."

[415] "fomes."

earlier. So foods alter plants, so much so that the marking-nut tree[416] bears a burning red fruit like a bean or a little almond, containing honey inside. It comes into being around the fires[417] of Sicily, and rarely elsewhere. It could perhaps be compared to the almond tree, for in addition to honey, a white stone is enclosed in the fruit like a small almond. It all turns dark with age, and thus through the quality of the Sun and the location, a very gentle plant turns into poison. Not just the region, but the site matters a great deal, for plants that accept the eastern sun grow quickly—those that receive the western sun, slowly. Because it has golden foliage, chrysocomos[418] has no leaves nor fruit, golden clusters, and a black root; it grows in dry shady places. It is therefore cold[419] and dry, and hence without leaves and fruit. Thus in the kind of plants as in that of animals, some maimed and dark individuals appear; nutrition thus alters everything. In Spain, milk has either no whey, or exceedingly little. Hence while attempting to coagulate it, they add water as well; the pastures are actually rather dry, so it is a case of "not everywhere nor always," a rule which is to be generally understood in discussing the errors of nature. Nature deviates, not of its own accord indeed, but through fault in the matter. Asses' milk has a minimum of &598 cheese, because of the animal's nature, and this makes it notably purging and healthy. There are in fact six parts in milk: foam, fat, butter, cheese, beestings,[420] and whey. And there is nothing to stop there being more. Whey is the watery part, which is left over after removal of all the fatty matter. Beestings are what some people call reconstituted milk, because when the butter and cheese are extracted by cooking, and the whey is collected, there are beestings, sleep-bringing and vigorously moist and cold. Further, foam, butter, and fat consist of the same matter, so that when one is removed, the remainder cease to exist. Fat is very sweet and attractive. And when milk is stirred by a piston in an empty cylinder, the better part of the fat is solidified into butter. The same milk when shaken makes foam. Overall then, as is the case in wine and blood, milk contains three parts: the watery, which is whey; the earthy, which is cheese; and the airy, which is butter. This also makes it obvious, as we have often said elsewhere, that there are only three elements: it is not actually possible to find more substances than these—not in olive oil, nor in honey, nor in milk, nor in wine, nor in [501]blood, nor in any other liquid. And even if there were a fourth element, it would be of no use. There are not in fact three elements in mixtures, but only two really, yet more if account is taken of the action of heaven. Fatty moistness in fact comes from wateriness, and the

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416 "anacardus."

417 Volcanic fires around the volcano Etna and elsewhere in Sicily.

418 χρυσοκόμη, a plant with a Greek name mentioned in Pliny, *Nat. Hist.* 21. 50: "It is a palm in height, flowering in clusters of shining gold, with a harsh, tending-to-sweet root, which is dark, and it grows in rocky, shady places."

419 Pliny (*Nat. Hist.* 21. 148) says it is warm!

420 "colostra."

fiery part consists of the earthy. Someone will possibly ask, "What is this fatty moistness, on which we have often conversed?" It is moist wateriness, which has supported the power of heavenly heat so long as to contain it.

&599 It is thus clear that this is the sort of thing that is made ready for soul and life, and therefore contains brightness too in itself. When water has settled into stillness, it picks up heat, by which it is changed, and gets suitable for the nutrition and generation of plants and animals. But then it is rendered more compact, because more loose-structured,[421] as fat is in comparison to oil, and oil to the sap of trees.

The fattiness of stones and all metallics, and metals, is like very rarefied oil, very solid and scanty, and has acquired no name with the Greeks or the Latins, because it is almost unknown right to this day.

The fattiness of herbs and of the pericarp of fruits[422] is a mucous juice; all the juice of herbs and leaves is like this; but we call it mucous only from its prominent feature, in which an obvious resemblance to mucus is apparent.

The sap of timbers is a fatty thing, seed oil is a fatty thing, animal lard or fat (or suet) is a fatty thing. As Man is a being[423] more excellent than the animals, his fat probably excels that of the others. It[424] glints, being full of temperate heat, and is hard to dry out or use up. It stretches into very thin lengths, equal and uniform throughout; it does not chill nor rot nor burn— or only with difficulty. As metallic heat is fuel to a fire, so is human fat to the conflagration of fever, and it does not split up.

In milk and eggs there is a great deal of moist fattiness—as there is a great deal of &600 food in milk, and a great deal of seed in eggs. So these items take on the function of food—human beings and carnivorous animals consume eggs just as they consume animals. There are then numerous parts in milk, which are separated by clotting. Milk is clotted by heat, not by any property of its own[425]—it is not alive, and is not coagulated by a living thing. This is the way in which heat coagulates milk: while breaking up the more rarefied part of the fatty moistness, it also breaks the bond by which the fatty moistness is linked to the watery part. This makes clear in how many ways it can be coagulated: it can be done by heat alone, while it is warmed in tin[426] vessels, and then the vessel is sunk in cold water—this is the soundest method. Or else it can be done by mixing in the

[421] "tenuior."

[422] Reading "et pericarpii fructuum" though 1554 and 1560 read "et pericardii fructum," which does not make sense here; the word "pericarpium" does appear on 612 (1560) of this Book.

[423] "aliquid."

[424] The following three sentences are only present in 1560.

[425] Reading "coagulatur autem lac à calore non proprietate ulla" with 1554, though 1560 omits "non."

[426] "stanneis."

rennet of a kid or safflower[427] seed, and the whey draws off the phlegm. Or else with fig milk, and then it purges both the bile and the phlegm. It is clear, too, from what has now been said that milk is clotted by the milk of any plant, and also by the reddish flower of the thistle, which also commonly emerges into the thistle's white down. And also by oxymel[428]—the healthy way for human beings. Milk's substance is also changed after being that of blood derived from foods; and so after buying a she-goat or donkey, it is possible with food to make medicated milk, either by giving polypodium[429] for black bile, senna to draw off every humour, or agaric or spurge[430] for dropsy, or earth smoke or hops[431] to purge blood, or a mercurial and mallow simply to unload the bowel. As I said, bodies are altered by foods, and firstly the blood, and the habits,[432] then the milk and the semen, and the &601 fetus, and finally the flesh and the powers, specifically like magic.[433] And so since the Germans are nourished mainly with the milk of beasts, especially cows, they are ill-tempered, fearless, and pastoral—bulls, that consume the same food, are like that. And since the inhabitants of the island of Corsica feed on puppies,[434] not just tame ones but also wild ones, they are ill-tempered, cruel, treacherous, daring, responsive, nimble, strong—that is the nature of dogs.

But if anyone makes use of wolf flesh (especially the heart), he will turn out far fiercer and more daring and deceitful. This is more apparent in animals than in human beings, and in plants than in animals, because they are not altered from other sources. [G]And while trees are altered by their nutrition, herbs are altered even more, and oftener: darnel into corn, and corn back into darnel, on almost the same basis that from blind cripples blind and crippled offspring are not begotten, but healthy ones—and yet from the healthy, blind cripples again. By the soil's and sun's strength, darnel passes over into corn, and imperfect things into perfect ones, and through weakness of each of these, perfect ones into impaired ones. Your[435] Poet, my Prince, expressed this change beautifully when he said: "Unlucky darnel and unfruitful oats are sovereign."[436]

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427 "cnicus" = "cnecus"—*Carthamus tinctorius*, or a similar thistle (*OLD*).

428 Mixture of vinegar and honey.

429 A kind of fern.

430 "tithymalum."

431 "lupus salictarius"; see Pliny (*Nat. Hist.* 21.86), there is little clue to the meaning in the context there.

432 "mores."

433 "propriè similes praecantationibus"—translation speculative.

434 "catulis."

435 I.e. Don Consalvo Ferrando, to whom the 1560 edition of the work was dedicated; he was the grandson of the Don Ferrando Gonzaga to whom earlier editions were dedicated. He became Duke of Milan from 1558 to 1560, and the Roman poet Vergil received his first schooling at Milan—hence this remark.

436 Vergil, *Eclogues* 5. 37.

And[437] wheat passes over into a softer variety in the third year, if it is sown in a cold moist situation, so that our soft wheat replaces the same ancient corn. However, it is agreed that there is a sort of wheat called "tosella," thicker and more rounded, from which the bread is lighter and much more attractive; but the &602 plant appears to lack the spikes of its ears, so that it looks more closely packed. Some people believe that emmer wheat[438] is soft wheat,[439] and certainly a very light bread is made from it. Whether this is so or not, there are some plants that are changed when cut back, such as the oak, which neither dies nor regrows intact, but usually changes into an oak of a less tall kind, an event that sometimes happens to broom for many reasons. However, established trees are quite obviously altered when twigs are grafted into the bark of other trees, such as peach into walnut, the tree then bearing small green bitterish hard peaches, suggesting a mixed nature of the two plants, such as occurs in mules of the donkey and mare. There should be right times for bearing fruit that suit plants, as is also the case in animals; when an early cherry, grafted belatedly into a medlar, draws in nutriment, the trunk does not provide it—when the graft supplies it, it does not draw it in, because the right time has passed, since it has already become chilled and lost its leaves.

People say that a vine grafted onto a cherry bears grapes too early—which does not happen always nor [502]everywhere. But there is a more successful technique in these cases: drill through the trunk of a cherry three years old or a little older. Through the hole pass a branch of a two-year-old vine which has started its growth nearby. Fill up the place with dung, then close with wax and tow, so that the projecting part of the twig draws nourishment from both plants. Then after two years in a warm neighbourhood, or three in a cold one, prune the branch off the vine near the cherry, so that the vine draws nourishment just from the cherry. And as this vine &603 will bear early grapes, so will grafts behave in the same way on an apple tree, and roses bear flowers in midwinter.

The plan is the same when flax seed implanted into onions produces a herb with the leaf of flax but a pungent taste. The nourishment should be appropriate. And on that plan I think a shallot[440] was devised, of which the shape and skins recall garlic, but the smell, taste, and substance recall onion. So it looks precisely midway between the two; the midpoint comes completely between everything either by nature or by technical skill.

Some trees turn their leaves at the solstice—for instance, the olive, the lime, the elm, the willow, the white poplar.[441] Others do it following the Sun's course in a complete semicircle in an individual day—for instance, the lupin, and the

[437] The following four sentences first appeared in 1560.

[438] "zea."

[439] "siligo."

[440] "scalongia," a word derived from the town of Ascalon in Palestine.

[441] 1550 and 1554 do not include the willow or the white poplar here.

heliotrope, and hence it got its name.[442] The cause of this latter rotation is the rarefied moistness relating itself to the Sun's heat, like hides to a fire[443]—since when itself placed near a fire, it turns towards it.

On almost the same basis, if flowers have been dried by the Sun's heat, being thin and porous, they are contracted at sunset when the cold comes on. But after drinking in the night humour, they are filled with juice and swollen, and have to open up with the Sun's morning heat. On the other hand, plants whose leaves turn round with the solstice have another basis for the marvel they perform. When leaves are in fact close to falling, because it is moist, they are turned more persistently,[444] and the change in the leaves because of this may be obvious. And so this occurs with all trees.

&604 But we notice it only in the leaves of trees whose household type[445] differs much in colour from the woodland type.[446] However, you would not have believed that this whole change happens on the day of the solstice—that would be something approaching a miracle—but that what happens gradually while it does its job is linked by human beings to the time at which it gets completed.

For example, it is believed of one kind of dwarf walnut, that it puts forth leaves, flowers, or fruit on the night before the festival of St John the Baptist. If this were so, what other more lucid piece of evidence for our religion against the stubborn Jews or the proud worshippers of Mahomet or the chattering philosophers could we want? But as I said, what happens to the tree's nature around that time is totally interpreted in relation to the cult of that most distinguished divine.

There are also members of the kind of trees and herbs, such as rue (I have already mentioned it), salvia, cabbage; and in the kingdom of Senega[447] there is a bean that grows into a tree, which has already been mentioned. This bean is produced in profusion from the tree. They are small and red, with a black eye. There[448] is another Indian one, the size of an almond, which I keep about me, and have tested. In no part does it fall short of the form of a true bean; but in size and in the substance both of its skin and its stone, it is very like almonds. The skin burns better than any pine-torch; it contains a lot of oil, and oil so pungent that its impact on the tongue is more than pepper's. For this reason it is regarded as &605 doing good to wounds in a wonderful way. The stone reproduces the taste of pistachio. Hence if it were the product of a herb, importing it would be

[442] The Greek ἡλιοτρόπιον means "sun-turning."

[443] "ut corii ad ignem"; "corium" or "corius" means an animal's hide.

[444] "tenacius."

[445] "pars."

[446] ". . . solum in earum foliis, quarum domestica à sylvestri pars colore multùm differt."

[447] See n. 319 above.

[448] The text from here to [H] on 606 (1560) below first appeared in 1554.

a very profitable business[449]—an oil extracted from the skins for use in lamps would surmount the expense. The whole pulp would serve as a bonus.[450]

Herbs that emerge in individual years because of variable climate are not changed so much as to lack seed or release infertile seed. But with the passage of many years and the failure of their powers, the seeds undoubtedly degenerate. But if things go according to your wishes,[451] in the following year you may provide yourself with the rich fruit of your effort. Frustration by a year's loss can do little harm.[452] But in the case of trees, a test of many plants is not so valuable, with the field's use being lost and the labour done in vain.

Whatever harm could follow from many unsuccessful sowings of herbs, all of it would be present in one loss of trees, if when sown they either did not spring up, or when sprung up did not mature, or when mature bore no fruit, or produced useless fruits. So it is risky to test in a large number of trees, and useless to test in few, because of the length of time required—and unrewarding even if it has worked out all right. With a long wait while we grasp that we have to repeat the procedure,[453] hope torments rather than encourages people. The first man to plant mulberries in the Milan countryside[454] reaped the reward not so much of a sage invention as of a bold one—but it was his successors rather than the &606 originator who won the prize.

But to return to the Indian bean: it grows in the region called Benin.[455] Among the local inhabitants, its skin is used alone instead of ginger, and they call it Unias. Benin is a district in the East, on the straight route leading to Calicut from Portugal. Our bean is the seed of a herb, as are the rest of the pulses.[456] [H]The reason then that a herb changes into a tree is more plentiful moistness, in a hotter and drier climate and soil. We have actually shown already that in general the kind[457] of herbs is moister than that of trees. But as in the case of dogs, there is nothing to prevent little herbs and ones that are dead[458] agreeing in their species with lively and large trees.

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449 In "non levis lucri provincia esset illum transferre" I have interpreted "provincia" as meaning a business undertaking..

450 "tota medulla usurae loco esset."

451 "re ex voto succedente"—this phrase does not appear to be classical and its meaning is speculative.

452 "frustratus annua iactura parum potest afferre detrimenti."

453 "rem."

454 "ager."

455 In Nigeria. Edmund Bohun (*A Geographical Dictionary* [London: for Charles Brome, 1693]) mentions that "here are 2 sorts of beans, both like horsebeans and of a disagreeable taste, not very wholesome"!

456 "ager."

457 "genus."

458 "morticinas," a word normally referring to animals that have died naturally rather than being slaughtered; meaning here obscure.

Recalling these topics reminds me to mention the nature of the oil coming into being in the kingdom of Senega.[459] In colour it emulates saffron, and tints feasts more than that does; its odour is that of violet, and its taste is that of our oil made from olives. The[460] best oil [503]in the past was that of the Titorenses in Phocis,[461] superior in colour and sweetness to that of Spain. Hence it alone was reckoned, so to speak, the monarch for the creation of ointments. Any oil-yielding seed is selected for having either the most plentiful or the best oil. Simply, olive oil is the best. Some, such as flax oil or sunflower oil, are good for diseases. Those that excel for productivity are olives, flax seed, nuts, almonds, sunflower seed, and turnips, and hena[462] herbs. But there are a number of others which are discarded through ignorance; all the stones such as those of cherry and plum contain oil. The skin of the Benin bean is to be &607 listed in the eighth place. And let this be the statement on oils, to serve as a summary on a familiar thing.

There is also a tree growing on the island of Porto Santo,[463] which is the first one for those from Spain making for India, that bears a fruit very like the cherry, but of a blue colour. I think it belongs to the cherry kind, but the variation among regions brings it about that its sap is used instead of lacquer;[464] it is quite red and shiny; it is digested into pastilles, and an old sap especially is thought to strengthen teeth. This sap either is fluid of itself, or is so also when the tree is wounded, and is then inferior to the original.

The next place of honour for this plant colour goes to woad,[465] the blue colour with which clothes are dyed. The common people call it "Guadum," and there is no other herb for which so much silver is paid out, since the revenue from such a cheap price runs to many thousand gold coins.[466] Although this herb is more profitable, the most beautiful of all is gromwell[467]—the seeds, which are stony hard, glint among its leaves with the glossy whiteness of pearls. I mean the Cretan type; the Italian one is considerably inferior.

But maybe someone will enquire about palm wood: why will it twist into an arch,[468] since the others when a weight is imposed bend into a curve?[469] The tale

[459] See n. 319 above.

[460] The rest of this paragraph first appeared in 1554.

[461] In central mainland Greece.

[462] Evidently henna, a shrub native to NE Africa, from which a hair dye is now extracted.

[463] Off Madeira.

[464] "lacca." 1550 read "dragon's blood" instead, and included two sentences surveying the views of Dioscorides and Brasavola about this.

[465] "isatis." 1550 used Pliny's word "glastum" here instead,

[466] The transaction here is obscure, the price being quoted in silver and then in gold.

[467] "lithospermum."

[468] "fornix."

[469] "sinus."

is a common one, and I also find that Theophrastus testifies to such a marvel. Xenophon is the authority that this happens also to pack-asses.[470] I think the reason is that it bends before being compressed; being already curved, it then bends upwards; it has fibres which are &608 oblique in one direction. Or if it can bend both ways, that is what occurs because of dryness, as also in the case of hides—a weight can be drying because of the pressure it exerts.[471]

Plutarch[472] thinks that since it[473] is rich in fiery power, it is stirred up by the weight, and then when dried contracts with renewed powers—or this happens because it gets stronger with the air driven out, and bends more the opposite way. To make one view out of many: when wood is stressed by a weight, it dissipates either moistness or wateriness or air; and so getting shorter, it retracts itself.

It appears that this occurs in a fashion similar to the case of mulberry wood, which never dries in air, but does so quickly in river channels and water eddies; since it is rich in very fatty moistness, it resists the air to avoid drying up. But moistness is dispersed in many ways by means of water, initially through the motion rubbing it off, and then the cold partly condensing it and squeezing it out, and partly chilling it. The wood itself is beautiful, solid and dark, and hence of use for many purposes. So both of these timbers undergo contrary effects from contraries.

What commands less astonishment is that statues sweat; the reason is to hand, since moist fattiness produces the appearance of sweat, when squeezed by the power of heat. Hence the statues that sweat most are those made of cedar, olive, vine, and cypress wood. This happens more when south winds blow, because the moistness is more plentiful and more rarefied. &609 But timbers that grow in sulphurous or bituminous soil, if they are of airy and fiery substance, and contain little earth and water (examples are the alder, the fir, the pine, and resinous ones), generally give off fiery sparks[474] while they are breaking, especially if already rotten. On a similar basis the barks of some of them are rendered so shiny white and glossy with age that at night they shimmer like hoar frost.

I will not be uneasy either about restoring to the list of plant miracles what Theophrastus recounts in his fourth book "*On Bushes*": that there is a herb imported from the Indus, and when he had chewed it he could complete sexual

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[470] "cantheliis asinis"—κανθήλιος is a beast of burden in Greek, and *L&S* gives also for "cantherius" an ass. For what Cardano says here, the best citation I find is Xenophon, *Cyropaedia*, 7. 5. 11: "For it is a well-known fact that date-palms, when under heavy pressure, bend upwards like the backs of pack-asses."

[471] The next two paragraphs are absent from 1550, which however states here that nature devised this plan in donkeys, to make them feel the weight less.

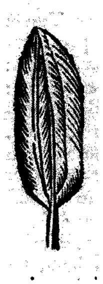
[472] The next two paragraphs are absent from 1550.

[473] Probably palm wood.

[474] Scaliger (*Exercitatio* 174 [566]) denies that sparks are given off by any tree unless it is decayed.

intercourse seven times in a day.[475] Whether this is true or not I would rather not say; for my present purpose it is enough to add that for sex[476] evidently two things are needed: breath[477] and semen.[478] Accordingly, in satyriasis the penis is excessively distended without the desire for sexual intercourse—likewise, nothing prevents there being a herb which on tasting does the same. But if it is eaten gradually, it will also generate semen gradually.

The[479] present-day Indians on the coast of Bethel always carry it for this reason—although they are not very highly sexed, perhaps because the district's nature weakens them with excessive heat and is discouraging.[480] When green, it seems particularly helpful to Venus. But if it is chewed, it blackens the teeth.[481] Its plant creeps like ivy. The leaf is &610 like laurel, marked with five lines, as you see in the figure. In size it exceeds the palm, and in smell and taste it mimics the laurel perfectly. There are internal veins nearer the edge than the middle. They are very obvious on the woodland portion.[482] So it is not malabathrum,[483] nor a plant known to Dioscorides. However, I have gone ahead with its discussion quite diligently, because a sizeable leaf of it when swallowed cheers people up marvellously—and so powerfully that it removes all anxiety about immediate[484] death, yet the power of sensation remains.[485] This is a notable feature; if you remove the power of sensation, you remove grief and fear, as in the case of those who are drunk or stupid, and those who have eaten the fruit



[475] Reference not traced.

[476] "Venus."

[477] "flatus."

[478] Scaliger (*Exercitatio* 175(2) [569]) points out that for sexual desire and intercourse, semen is not necessary—only for reproduction. Eunuchs copulate, he says, some of them with vigour.

[479] The following two paragraphs with one subsequent sentence first appeared in 1554.

[480] Here 1554 includes a statement that Bethel is what the workshops call an Indian leaf which the Greeks call malabathron; see n. just below.

[481] This feature appears to identify it as betel nut, the seed of *Areca catechu*.

[482] "sylvestri parte"—meaning unclear.

[483] "Indian Bay"; the shrub *Cinnamomum malabathrum* grows in the Western Ghats of India now; its leaves contain an aromatic oil and are still used as a spice. Malabathrum is also mentioned in the culinary work attributed to Apicius, the Roman gourmet of the early Roman Empire (*De Re Coquinaria*, 1. 15), and frequently by Galen (Durling, *Dictionary of Medical Terms in Galen*, 228). This and the three preceding sentences first appear in 1554..

[484] "instans."

[485] "sensu tamen stante."

of sleepy nightshade[486] or strimonium.[487] But to be able to discard anxiety and all fear while the power of sensation remains is marvellous and rare. The Turks are said to use opium for this reason. But some people attribute this to saffron. Similarly, to stir up sexual desire the Indians often use a medicament called "Amphiam," which the Spaniards say is opium.[488]

So some people enquire, rightly and with good cause, how poppy juice[489] (which is excessively cold, and so much so as to kill) can excite [504]sexual desire. And so they suppose that poppy juice is different from "Amphiam." But "Amphiam" too is a poison among the Indians, and poisons of the sort that kill without distress—everyone knows that this is a property of poppy juice.

However, perhaps it is something different, and relieves anxieties, and stimulates sexual desire, and brings slumber—something like amomum[490] and saffron. So we have shown that there are some agents that stimulate &611 excessive sexual desire—and what they are we will also explain in the complete account of plants.

Now it is appropriate to explain why flowers do not all have the same colour, as leaves do. This happens because the moistness is dried up and no more is supplied. Since a continuous moistness is supplied to leaves, with the action of heat they all have to be green, which is why the upper surface of standing waters is like that too, and so are wet places lying below the drops from roofs on the ground, where the Sun's rays do not reach. Thus in the whole plant the wettest point always, and generally the coldest, is the leaf; the hottest and driest is the seed; in the middle between these the flower is to be placed. There are flowers too that are green in some portion, and in another blue—people used to say it had the form of a basket and belonged to the hyacinth kind. With very little odour, and rather moist.[491]

Furthermore, the root is the coldest and driest part—just as the fruit is the hottest and moistest part. In the middle between them is the trunk, but coming closer to the root. Then again, the hottest and driest part of the trunk is the bark, the moistest and coldest, the pith.[492] The wood is located in the middle between

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486 "halicacabum."

487 "strimoniae"; but "stramonium" means "thorn-apple," and the toxic effects of stramonium are nowadays listed as including "confusion, hallucinations, noisy delirium." So perhaps stramonium was meant here.

488 Scaliger (*Exercitatio* 175 [568]) says that the "navigatores Indi" concur in this identification.

489 "meconium," a word which Pliny uses to mean poppy juice—and also to denote a plant, and the normal discharge from the bowels of the newborn, known nowadays under that name.

490 An Eastern spice plant of that name (in Greek, ἄμωμον).

491 The preceding two sentences are inserted first in 1560.

492 "matrix," which does not have this meaning in classical Latin.

them, so to speak. But as I said, the trunk as a whole is cold and dry. Leaves cover the stem, the flowers, the fruits, the seed; like the bones in animals, the wood supports everything, and is covered by the bark for protection. But in certain instances it is also the bark through which nutrition is conveyed; the pith too in some instances is for nutrition. In all, it moistens the wood.

&612 Hence all those without pith abound in sap—for instance, guaiacum. Those that have a profuse substance of the pith lack sap—for instance, the elder. The root is for the sake of drawing nourishment from the earth, the flowers are on account of fruit, or seed—for they always turn into these—the fruits are on account of seed, for it is contained in every fruit under the pericarp. So the fruit is seen as the consummation[493] of a plant, but the seed is for propagating the species. In cases where there is no fruit, the seed provides advantages and uses.

Nature appears to have treated plants less kindly than animals over this, since in winter plants shed their apparel, but animals grow more—their fur.[494] And nature has armed plants as it has armed animals, with hardness, size, ability to bend easily, and also spikes.[495] Nature has in fact fortified leaves in four ways: with the thorns of roses (as I said), and with lesser prickles, as in the case of borage;[496] with wool, like wild mint; with hairs, like those of the violet and each sort of mouse-ear hawkweed.[497] Fur is thicker than wool, and therefore has no equal for consolidating wounds.

As in the case of animals, errors do appear, and are more common the more worthless they are; so they are frequent even in tiny animals, in those that are begotten from rotten matter, and in fishes and in metallics, just as they are in plants.[498] But in animals that are, strictly speaking, more perfect, monsters are so called because of their rarity, from "indicating something"[499]—the name can extend to plants too. If plants are to preserve their own rank, they are not only consistent in having fixed parts, but also in the number of leaves.[500] Nature was &613 so cunning too in details—grasp the reason for this: since plants lacked

[493] "perfectio."

[494] "pili."

[495] I.e. presumably thorns for plants, claws for animals. The following two sentences first appear in 1560

[496] A bristly blue-flowered plant.

[497] "pilosella": *Hieracium pilosella*, also known as *Pilosella officinarum*, the *mouse-ear hawkweed*, which does have long white hairs, though there are other plants with "pilosella" as first or second name.

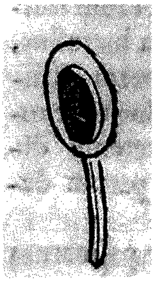
[498] Scaliger (*Exercitatio* 177(4) [174–75]) disagrees; with the exception of "lolium" (darnel, tares), he regards such deviations as rarer in plants than in animals.

[499] "monstrando."

[500] Scaliger (*Exercitatio* 177(5) [575–77]) denies this, and has counted lettuce leaves to find out: "inveni te illusisse nobis." Yet the idea dies hard: the Modern Greek word for a rose is τριαντάφυλλο, the flower with thirty leaves or petals.

the ability to move for generating, it was essential to have collected both sexes together, so that a number very often combine into one.

Thus in animals, just as in ships, a single spine was essential, into which all the bones could be implanted, and in plants the fibres performed the role of the spine. It was therefore necessary (as in the case of the fibre of plants if there were a single one, or in the individual ones if more) that leaves should grow out on the other side, right and left on equal terms, and then branches; in animals too, everything is seen to be duplicated, as Aristotle rightly mentions. So, as a leaf was essential on the topmost point of a cutting,[501] but twin leaves from there onward on the knots of any plant possessing a single spine, it was a necessary arrangement in this ranking that on individual knots it should have two leaves, and on the topmost one three.[502] And so, when the plant was dry, and could not put forth leaves, near the knots a "lone leaf"[503] is created, of which this is the shape.



A single leaf springs from a short stem without veins and fibres, a stem very like the softer ivy type, and where the leaf joins the stem, a sheath comes forth at the same point, wrinkled, thin, and green, longer than a leaf, in which small seeds are contained. The whole herb is quite green, the single root has the form of a serpent's head, and since it springs up in meadows in April, it dries up near Pavia in May. It has no smell, and from its &614 taste is regarded as good for wounds. And so, since matter was not available here, the leaf needed to spring from the fibre and at the cutting; otherwise the whole plant could not be protected.

On this basis it[504] is fatty and scanty in the "lone leaf"; medium and scanty in the clover;[505] but fattier in the hellebore—if it had been thin, it would not have been necessary to make so many leaves. In the cinquefoil[506] and the heptaphyllon[507] it is very thin, because the scanty matter would have been reduced into scantier leaves if it had been thick. Fourthly, there are in fact more leaves if the stem has not been thick, so that they need to be thinner. Further, where the

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[501] "cacumen," which can bear this meaning.

[502] Scaliger (*Exercitatio* 78(2) [579]) makes heavy weather of this "three" contrasting it with the "lone leaf," but probably Cardano sees the lone leaf as springing from the same knot as a conventional pair.

[503] "oenophyllum"—but neither in this form nor as "enophyllum" is this word in *OLD*, *L&S* or *Liddell&S*. Scaliger however (*Exercitatio* 178(2) [578–81]) solves the puzzle by reading "Henophyllum," i.e. "single leaf," or "lone leaf," although the Greek 'ἑνόφυλλον' is not to be found in *Liddell&S*.

[504] The matter, presumably.

[505] "trifolium," i.e. with three leaves.

[506] "pentaphyllon," with five leaves; *OLD* reports that Pliny confused this with the wild strawberry.

[507] This plant name means, "With seven leaves"; though there are references and dictionary entries, none found leads to any identification of it.

matter is dry and scanty, there are few fibres or none (as in the "lone leaf," clover, and cinquefoil)—where there is a great deal, there are more fibres, as in trees. Any fibre maintains its order; when there have been more of them, they seem to muddle the order and number of the leaves. Stellar movements consist of numerous equal motions, and so look muddled and uneven.

It is thus already clear that the leaves on the highest point of plants have to be uneven in number. Either they emerge from the fibres alone, and a "lone leaf" is created, or from different points,[508] and [505]clover, cinquefoil, heptaphyllon, and hellebore (which has nine leaves) are created. If indeed there are more, it is better for two and two to be distributed near the knots over the whole plant, and the cutting does not have to carry so much of a load.

But on a contrary system, if there are few it was better for them all to be transferred to the top of the plant—leaves there &615 better protect the whole plant, and consequently also the flowers and fruit. The evidence is that the leaves are created to protect the flowers and fruit, since the leaves are formed before the flowers, and long before the fruit. And where the leaves are permanent,[509] there are also fruits or flowers throughout the year. And if the leaves come into being later than the flowers, most of the fruit perishes, and when the leaves fall in the winter, no flowers nor fruit come into being, and leaves seem to be created just for this.

Then the leaves of plants are unequal, since those at the cutting have to be unequal, and thereafter others appear on both sides, equally right and left. This shows, firstly, that no plant which has a bare trunk can have equal leaves on the tip; secondly, that a middle leaf always becomes larger, fatter, and stronger than the rest, and ones nearer it are larger than those further away; and that on the opposite side to the fibre there is always an adjoining cavity in the stem, and the trunk bends more readily into the cavity than into the fibre.

On the same basis, the fibres[510] of leaves are also unequal, as in the case of the plantain; there are either five, or seven, or even more; in fact a central one is added over and above pairs that lie to the sides. But if the matter of plants has been ample for the leaves with a single fibre, still on the same basis they would be unequal on the cutting, but throughout the plant two and two on individual knots. Yet if there are too many fibres on the trunk as pairs, there will be sets of four on the knots, or &616 two and two, but not from the same position—but on the cutting, groups of sixes or tens. The same system applies on the branches, so that (unless some damage or something to create a monstrosity has occurred, a common occurrence in plants, as I have said) in all cases one can arrange the number of leaves on a definite plan.

[508] "hincinde."

[509] "continuus."

[510] "nervi"; on this word see n. 46 above.

And similarly in the case of the fruits: let me take an instance from a difficult point: pomegranates that each grow according to their kind and from the same tree retain a fixed number of grains, some 944, some 128, and some another number, with all of them making from the wider circumference of the bark in a fixed array towards the narrow centre. Pear seeds are similar, and those of apples or medlars. They[511] are all tethered by little stalks, because watery moistness is better dissipated by the air in this way, and the fruits are also better nourished because of it. But the seeds held in these, for whose benefit the fruits are created, turn out sturdier, and their generation is better adjusted.

Evidence for this is that mulberry fruit grow on the trunk without a pedicle; since this tree possesses (as I said) very fatty moistness, it has no need for its humour to be further dried on a pedicle. For these reasons it produces fruit four times a year, fruits which do not ripen unless the tree is injured. There is a decision we have to make in the case of the fig and vines, which fruit more often in a year: the fruits have a profusion of fatty moistness, and mature late or with difficulty, and are heavy in the stomach, as is mulberry. &617 The tree ought to be of a sort that would bear a fruit so abundant that the inhabitants would treat it as corn, and it would meet the needs of human life.

Accordingly, plants that produce a single fruit and quickly mature have little fatty moistness, and get so mature that they quickly rot, like cherries; those that do not mature, yet have a single fruit, are cold and dry, like service berries and medlars; those that produce multiple fruit, like the fig, the vine, the mulberry, all bring the final fruit to ripeness with difficulty, and are very moist, and people feed them a lot with fatty moistness, and they are concocted slowly.

Some fruits are stored after picking and dry up, like walnuts and hazelnuts. Others such as pomegranates are stored but do not dry up; others such as cherries are not stored. Those that are stored dry turn green again, as if just plucked from the plant, if the skin is perforated and they are placed in a bag and let down into a well for eight days, or are buried for fifteen days under moist earth. Cato's[512] teaching was that these and grapes not yet ripe are stored in glass vessels underground.

There is much that relates to these topics, but does not include what now needs to be covered to complete the account, such as the fashion in which plants are to be transferred from one region to another, for instance from India to Italy. Some through transfer of seed, others complete in vessels and covered in &618 earth, twigs of others buried in honey. Since the moistness of honey is rarefied, sweet and temperate, not fatty, it is not liable to decay, and very well suited to the

[511] The remainder of this paragraph and the following two are first present in 1554.

[512] Marcus Porcius Cato "the Censor," in addition to important political activity at Rome, wrote his *De Agri Cultura* about 160 B.C. and drew on his personal experience of the new capitalistic farming to advise in that work on the cultivation of fruit, olives, and grapes, and the management of flocks and herds. This sentence appears first in 1560.

nourishment of tender shoots. Consequently too walnuts are kept green a whole year in it, and fruits and meat for quite a number of days without decay.

But after the juices have foamed up (this is the way that watery moistness, which is the basis of decay, breaks down), they are preserved by pouring oil over them. But the juice of fumitory[513] passes across from bitter into pungent and acid in this way, since the earthy part, the cause of the bitterness, leaves a tasteless juice behind as it descends. When this is impaired by air, it passes across into acid, like all sweet and tasteless things. So the best thing is to have cooked it for a long time and stored it in a very cool place.

All decay, as I said, is hot; therefore truffles that are forming are liquefied by snow lying directly above them; while the putrid heat separates the earthy moistness, it generates roots without a sprout, called truffles. Contrariwise, when it concocts cold moist rarefied matter, it puts forth sprouts without roots, which we call fungi. And so fungi are moister, but truffles give less anxiety.[514]

As[515] a rule we do our preserving to prevent decay with dried or chilled things, or things covered with moist fattiness. What rots has to be &619 watery, so as to possess moistness and [506]to decay from heat. Dry things that are either completely cold or very fatty cannot decay. There are three ways to get anything dry: with lively heat (a triple approach: fire or smoke or Sun), or by scouring off the moisture (by wind or salt), or by a gradual drying agent, such as aloes or myrrh. Decay does not befall chilled things, so that many things do not decay in ice. And[516] among the Sarmatians fish are kept fresh for five months. And eels dried in the wind and eaten raw taste pleasant. Further, corpses covered in mercury are preserved, provided that the metallic can make its way inward too. Moist fattiness preserves anything little liable to decay, such as sausages,[517] meat salted with oil, and roast (or rather fried)[518] fish, although this method also merits inclusion with the complex ones. Some things are preserved by a mixed cause,[519] for instance things which are preserved by honey, like most fruits, since it is fatty, and dries—or by vinegar, which simultaneously dries and cools. So although decay is a route to fire, nevertheless it is not the things that decay that take fire, because they still possess watery moistness, but the things that remain

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[513] "Fumi terrae succus"; the plant "fumitory" draws its name from Old French "fume-terre" because it appeared to extend so rapidly over the earth, like smoke (Grigson, *Dictionary of English Plant Names*). So the juice of fumitory (*Fumaria officinalis*) may be indicated here.

[514] "securiora."

[515] This paragraph appears first in 1554.

[516] These two sentences appear first in 1560.

[517] "farcimina."

[518] "frixus," while classical Latin has "frictus" from "frigo," to roast thoroughly.

[519] "Quaedam verò mista causa . . ."—the meaning is not entirely clear.

after decay. Now the fungi such as truffles do not take fire, because decay is a product of fattiness and wateriness mixed; they are not the residue from decay.

But laurel leaves, which are a residue after some decay and are dry, blaze up fast—juniper &620 too, because of its powerful dryness. But because they catch fire fast before the watery moistness is ejected or dried up, they inevitably crackle. This then is why laurel and juniper leaves crackle vigorously while they burn. There are those who believe that divining can be done with burning laurel leaves, either because the tree itself is sacred to Apollo, or because their flame flickers about in various forms, or because its nature includes something that stirs the mind. There[520] were people who thought that a kindled juniper trunk covered with its own ash holds onto fire for a year. As long a period as that would certainly be a marvel—but just for a long time is no marvel; its substance is quite compact and fatty, and not liable to spoiling by use—apart from its growing poorly in our part of the world, and where it does grow, it is called "cedar."

Cedar differs from juniper only in the redness of its fruit and in its size. The sap of juniper is called varnish;[521] it is useful to sprinkle on paper to prevent the ink spreading out; because it is dry and thin, it absorbs liquid and halts its motion. Although pumice is dry, it is not absorbent, because it is thick and without heat. Again, if you squeeze just with your thumbnail a piece of paper already scraped, the ink will be less scattered than if you add pumice powder. This is why a &621 liquid varnish is made from dry varnish and linseed oil, very suitable for resisting all the weather's attacks—hence it is often applied to paintings. In the past, very thin wax, or white of egg, and artificial vermilion[522] or chalk were used instead, along with nitre. Pictures used to be protected with wax against the Sun's heat and the winds and damage from salty rain and vapours. With white of egg and vermilion, even a purple warmth was contributed as well as protection. But chalk and nitre give a delightful glitter.

Apelles used to protect pictures from dust and dirt and other injuries with a very thin ink (that liquid was named from its use, not from its heat[523]) and in addition added a great clarity to them, with the reflection of the light.[524] All

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520 The remainder of this paragraph with the three subsequent paragraphs first appeared in 1554.

521 "vernix." See n. to Book II at 92 (1560).

522 "sandix."

523 The relation to heat is not evident. "Atramentum," the word for "ink" here, is derived from the adjective "ater," which means "black,"

524 A very celebrated Greek painter of the 4th century B.C. For details of his many works and the tales about him, see *OCD*. On his varnish, see Pliny, *Nat. Hist.* 35. 36 (trans. Bostock/Riley): "When his works were finished, he used to cover them with a black varnish, of such remarkable thinness, that while by the reflection it gave more vivacity to the colours, and preserved them from the contact of dust and dirt, its existence could only be detected by a person when close enough to touch it. In addition to

these benefits in our own time are also contributed by varnish. In pure form it enjoys favour for not impairing colours; it is transparent, very thin, bright, so that it lightens and does not blunt colours. It reflects the actual illumination, and is so solid and durable as to stay undamaged and everlasting against water, wet brine, winds, dust, and the Sun.

But[525] to return to my account of plants, a frequently asked question is: Why do some of them have crinkly leaves, and others leaves forming a head, as cabbages do? The reason is plentiful moist earthiness. The fibres grow later on, being earthy, but the substance of a leaf is moister; since its contents are not &622 readily separated, being compact, it bends and has to crinkle. The plants that have crinkly leaves are of this sort: like the lettuce, elecampane,[526] sorrel. Those that are stretched out are endowed with either thin or scanty moistness. The headed ones are very crinkly, or more sluggish, so that they do not separate, but gather together and extend round the same point.

I am aware that I have brought my account of plants to an end, but since I have explained the composition of red and scarlet ink,[527] I shall explain that of the rest too. Blue is from blue earth, or the Cyan stone;[528] gold from purpurina[529] or gold; and all the other colours are made from metallics, by both precise methods, the methods by which we have explained above that red is mixed from cinnabar.[530]

Black, the common one, is made like this. Take a pound of fresh crushed gall-nut; of Arabian sap, of ripe privet berries, of each half a pound. Macerate them for a week in six pounds of water. Afterwards boil them till a third part of the water departs. While it is boiling and moved away from the fire, add a pound of copperas finely ground. Mix everything till it cools, and after ten days, strain it through a fairly dense cloth and preserve it.

In antiquity, soot from baths and furnaces was in use for writing books. And now printers use soot of flax oil, along with the oil itself. &623 I know who made

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this, there was also this other great advantage attending it: the brightness of the colours was softened thereby, and harmonized to the sight, looking as though they had been viewed from a distance, and through a medium of specular-stone; the contrivance, by some indescribable means, giving a sombreness to colours which would otherwise have been too florid."

[525] This paragraph appears first in 1560.

[526] "inula."

[527] At 584 (1560) in the present Book. The discussion here of the inks used was briefer in the 1550 edition.

[528] *Lapis lazuli*; see Book V, 386–87 (1560).

[529] This is probably a relatively modern Latin word for gold leaf, but is certainly not classical.

[530] At 585 (1560) in the present Book, and see n. to Book II at 137 (1560).

a very good one, yet six months later it vanished entirely from the pages, with great mischief.

So the reason for this requires investigation. As we know, earthy things persist, but not moist things; and what is rarefied vanishes very fast—hence alcohol disperses instantly. Copperas reduced to spirit and mixed with tenacious matter can bring this about. Hence what is reported as a great miracle about Apollonius of Tyana[531]—that he was twice accused, but his accuser found a clean sheet, whether the accuser was the Emperor [Nero] or Tigellinus—if indeed the tale is true amid so many [507]shameless lies and mere fables of Philostratus, it might be totally without any miracle.

But lettering that lacks this technical skill is deleted in many ways—either with a very thin steel sword, or with the dust of our alum, which I have often found of use, or with distilled water, copperas,[532] saltpetre, and larch sap. And "seconds"[533] are deleted by water; they will be described later for the removal of hairs. But more knowledge is involved in the manner of use than in the discovery. Indeed, if lettering needs deletion by powder, the powder should be rubbed lightly with the fingers. If it needs deletion by a sword, the sword should be handled quickly and very lightly. If by water, look out in case while you are busy scraping the &624 lettering, you tear the paper. To sum up: do not handle such a delicate business roughly.

We have spoken so far about the Elements, Heaven, Light, Mixture, Metals, Stones, and Plants. Let us move on to an account of animals, and firstly to the insects.

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531 A wandering Neopythagorean sage of the first century of the Christian epoch; his birthplace Tyana is in Cappadocia in Asia Minor. His biography was composed by Philostratus (see Bibliography), and a Latin translation accompanied its Aldine *editio princeps* in 1502, thus being available to Cardano. This biography (4.42.2–4.44.3) recounts how Apollonius was brought to trial before Tigellinus, the prefect of the Emperor Nero's Praeetorian Guard (A.D. 62–68), but the text of the denunciation prepared by his (unnamed) accuser was mysteriously obliterated by the time it reached the hands of Tigellinus. Apollonius was subsequently arraigned before the Emperor Domitian (Philostratus, book 8), but no further marvel appears in that case.

532 "calchantum"; on this see n. to Book II at 131 (1560).

533 "Delentur et aqua secunda, quae inferius describentur ad tollendos pilos"; no dictionary mentions this meaning of "secunda," but it may be surmised that it indicates cases where the scribe's or printer's ink carries over from one page to another.

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On Animals that are Generated from Decay

There are two primary kinds of animal: the first is the one that has an indented portion and preserves life in it; it is called an insect.[1] This is related to imperfection, because the same thing happens in plants. The others are the perfect animals, to which this hardly is appropriate at all. But[2] an overall[3] account of the animals needs deeper enquiry, and first, into why animals do not grow so much in a straight line, like plants, but rather grow in width and depth. Next, why nature has generated some animals from seed, but others without it. Finally, why some animals feed on others, but some only on plants. It must not be regarded as the same thing for animals to be generated from decayed matter, or for them to be imperfect, or for them to be insects—lizards and snakes are reckoned among the insects,[4] and yet are not generated from decayed matter, but from eggs. And vipers emerge from a womb, though they are born from eggs—but it is the animal, not the egg, that gets born, because it is freed from the egg in the womb. Again, mice are generated from putrid matter, but are not among the insects. Further, many of the snakes possess all the senses, and yet have their origin from pus as matter. And so it is not inappropriate for a perfect animal to come into being from putrid matter, just as conversely an imperfect[5] mole comes into being from an animal of its own kind.

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[1] The word "insect" means in Latin "incised," hence this remark.

[2] The material from here to [A] on 633 (1560) appeared first in 1554.

[3] "communis."

[4] The inclusion of lizards and snakes among the insects does not appear to be Aristotelian (it is not to be found in Aristotle's *Historia Animalium*), but might possibly be an extrapolation from his definition of "insects": "And by 'insects' I mean such creatures as have nicks or notches on their bodies, either on their bellies or on both backs and bellies" (Aristotle, *Hist. Animal.* 1. 1; 487a33–35; trans. D'Arcy Thompson, 1. 1).

[5] Since it cannot see.

&626 [wrongly numbered 526] So let the discussion here cover serpents, then insects— thus this treatment is not pure and general, but since the greatest part of the insects is born in this way without an egg or a womb (not to mention a parent), and likewise the great number of snakes in the same way, I have accordingly decided to deal with all these here. Furthermore, to return to my planned discussion: the reason why plants mostly grow straight up, but not animals, which instead grow in width and depth, is that the humour of animals is fattier, and so expands more in all directions; the heat of plants is in the root, and so propels it in the direction in which it has more power to break out. When it has broken out, it cannot so easily depart from its earlier direction[6] of movement. The result is that in soft earth the plants turn out more thick and less tall, and contrariwise in solid earth near waters; that humour is less fatty.

What needs to be shown is why some animals feed on plants only, but others on other animals. It was impossible for there only to be animals that fed on the flesh of others—with one consuming another and no other food available, and always some of the waste material piling up at the place, the whole mass of animals would start by diminishing in quantity and number, and finally—and quickly too—would fail. But if all the animals fed on plants, nature would not have reached perfection, since that important[7] blood and flesh would not consist of broken-down[8] and well-tempered elements. This is why no animal not fed on flesh is wise and prudent—except the elephant. &627 Thus nature could not create wise birds, nor fish nor animals that are provided with feet alone[9] and possessed cleverness, wisdom, and human practices.[10] Those creatures that make use of flesh are in fact closer to man in their power of sensation than those that make use of plants—examples are dogs, wolves, long-tailed monkeys,[11] cats, lions, dolphins, bears, eagles.

Thus there are three kinds of animals distinguished by their different foods: some, for instance horses, asses, oxen, sheep, goats, feed on plants alone. Some, for instance lions, dolphins, panthers, feed on animals alone. Some, for instance human beings, long-tailed monkeys, hens, pigs, feed on both. Those that feed on animals, if you except the animals that serve them as food, are polite[12] to the

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[6] "forma."

[7] "ille."

[8] "confractis."

[9] And no hands.

[10] "Non ergo aves sagaces, non pisces, non animalia pedibus solis praedita, solicita, sagacia et moribus humanioribus facere poterat." The syntax is somewhat contorted, but the overall subject is "nature."

[11] "cercopitheci."

[12] "civilis."

rest—as the crow is to the fox, the lark[13] to the kites, the fox to the snake, the crocodile to the goldcrest,[14] or the bass[15] to the grey mullet. But of those that used to feed on plants and needed blunter teeth,[16] some were armed by nature with hooves, for instance the horses, asses, and camels; others with horns, for instance the oxen and goats. And since for little animals the protection given by hooves and horns slowed their flight, and afforded little help because of their weak powers, nature withheld both from them, for instance from the hares and [508]rabbits. But it armed all the wild beasts, and those that feed on flesh, with teeth, and very sharp ones, except in the case of birds—in these it created a hooked beak. But on almost all those not given teeth, such as birds, or given weak ones, such as cats, and on similar creatures, nature bestowed strong curved claws. Thus nature provided carnivores with teeth and claws, and milder animals with horns or hooves, if they were big, and small animals with speed.

&628 [wrongly numbered 689] With this once grasped, what is left for me to explain is why some animals are generated from decay, others by propagation. The reason for the difference is that nature wished generation to require very tiny things,[17] and so originally aimed for generation to occur in all animals from putrid matter. But since the perfect animals required a long time to be brought to completion, the matter would not have been capable of preservation for so long without movement, particularly without a receptacle to face the changes occurring over time. A womb was thus required, or an eggshell, in which the fetus could be preserved till its completion. And this too involves generation from seed. So it is clear that nature's sole intention was generation from decay, and its rapid completion. The rest was imposed, and not nature's intention, but came later. In the creatures in which generation without any assistance was available (as in the worms in fruits), nature required nothing; in other cases, it employs filth[18] without definite matter, as in the case of flies. The more perfect creatures are generated from definite matter which the animal itself befouls—like bees from honey, which they pour forth with their refuse—and hornets similarly, from wild honey. Other creatures need an egg.

But the most perfect are those generated in a womb. In these five orders, nature has reached the peak of perfection. Enquiry into whether the generation

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[13] The word here is "pifici," and has not been identified. It might correspond to the Greek πίφιγξ or πίφηξ, a bird mentioned in Aristotle (*Hist. Animal.* 8 (9); 610a12; Loeb 3: 231), possibly a lark. It is not mentioned by D'Arcy Thompson (*Greek Birds*).

[14] "regulus"; the goldcrest's official name is *Regulus regulus*, given by Linnaeus.

[15] "lupus piscis."

[16] 1554 here includes a few words to explain that the bluntness avoids breakage but makes the teeth useless as weapons, and that to avoid overloading the brain, the front upper teeth were absent

[17] "paucissimis."

[18] "colluvies."

of things generated from putrid matter goes on all the time, and into whether they ever fail, is a question for my books *De arcanis aeternitatis*.[19] While books are actually being written, they are in mind,[20] but these are eternal questions.

Thus generations &629 from seed and those from putrid matter differ in this, that in seed there is matter which receives heat always like the heat from which seed is generated, in other cases, there is a heat, but what happens is that the matter is either here or there, so that the generation of such things is fortuitous. So most of these are very small, and imperfect—very small, because not much matter is to hand suitable for generation when it is collected by chance, and imperfect, because such generation has little peace, and is therefore done quickly. And what is done quickly, as with works of art too, cannot be perfect.

Therefore absolutely no animal generated from decay can have perfect and complete senses, although possessing them all; they lack all the external senses, and much more the internal ones, indeed they totally lack prudence, and are stupid. But bees are prudent; they are generated from particular matter, and do not lack a parent. Or if they are generated from a calf, the work is nature's and not their own—like the painting of the flowers of a hyacinth, which no sane person attributes to the plant's prudence, but to nature. Ants do appear prudent, but originate from seed and eggs.[21] The result is that no animal generated from putrid matter is capable of training[22] or of being tamed; the principle of learning is not inside them. But the basis of size is a different one, and is an unreliable measure, even if most things, as I said, are small. It is in fact due to the kind of animals, not to their generation. But Aristotle denies that such animals generate, and is right,[23] yet not &630 because an animal of a different kind is born, on the basis of matter. But I will explain the real cause of this.

The ability[24] to generate is an obligation of the sturdy and perfect animals. The evidence is that they do not generate mutilated and damaged and very small offspring, or not often, and not like themselves. From imperfect creatures, weakened by old age or disease, or who have not yet grown up, there cannot be

[19] For full details of the history of this work of Cardano on the *Secrets of Eternity*, Maclean, *De Libris Propriis*, M44 should also be consulted. See also n. to Book I at 5 (1560).

[20] "mens sunt."

[21] 1554 gives here a sentence about a worm created in a hazel nut and nourished by milk, which grew to huge size; not in 1560. 1560 replaces it by this one.

[22] "disciplina."

[23] In *Historia Animalium* (5. 19; 551a1–13; Loeb 2: 281–3) Aristotle remarks that "out of these [creatures generated by spontaneous generation] nothing further is produced." H.B. Adelmann, *Marcello Malpighi and the Evolution of Embryology* (Ithaca: Cornell University Press, 1966) discusses the history of thought on spontaneous generation especially at 743 and also elsewhere; Malpighi (1628–1694) did not believe it occurred.

[24] "virtus."

generation. So the animals generated from putrid matter, being mostly feeble, do not generate—or if they do, they produce something weaker than its parent, as do lice, nits, and mice—mice generate other mice in which the generative power was so weak that they could not generate something like themselves.

What remains, then, is that the animals generated from decay mostly do not generate at all; some do, but feebly, and not to produce their own like. A few in a hot region such as Egypt, or through good luck, are sturdy, and pass across into a continuing kind, and are propagated like the rest of the animals.

Those that do not generate are not sterile for the reason that they were generated from putrid matter, but because after being so generated, they fall below the perfection of their kind, and this leads to most of them being monsters. The famous question is thus settled, whether the mice generated from putrid matter are of a different species from those that are generated by succession. Certainly not; the form is the same, and the activities, but they differ only as a monster differs from an intact animal &631 of its own kind. No one will actually say that a human being with one eye, or six-fingered, or from whose womb the back part of an infant protrudes, is an animal of another kind from a human being—a monstrous human being is what that is.[25] We will therefore call the mouse generated from putrid matter a weak and monstrous mouse. Thus nits are monsters produced from lice, and all such monsters[26] are not actually a species. I am quite dumbfounded at Aristotle, because although he allocates so much form to everything but so little matter, in this situation he gave the matter precedence over the form, it being evident in this distinction between animals that nothing was lacking for a full form and shape and way of life[27] except the power of generating, which is also lacking in castrated animals, weak ones, old ones,[28] and those that are too young.

But if this was just a mistake of Aristotle's, and there is nothing lacking in its context so that it is rather other people's conclusion, Theophrastus certainly corrected the mistake—a man to rank above Aristotle, in Galen's view, and rightly, if we pay heed only to the writings we have. The inferences from Aristotle's [509] writings (which are at many points corrupt) are straightforward. The soul is determined by the heavenly heat, and all species have their own number. Provided a species is capable of taking on a form, it is not changed on account of the matter. Divergences due to the matter, such as occur in those that are generated

25 On monsters see A.W. Bates, *Emblematic Monsters: Unnatural Conceptions and Deformed Births in Early Modern Europe* (Amsterdam: Rodopi, 2005).

26 Aristotle (*Hist. Animal.* 5. 31; 556b23–5; Loeb 2: 209) says that from lice etc. nits are produced, and *from them nothing further*; this is presumably the reason for calling them "monsters."

27 "mores."

28 Reading "senibus" with 1554 instead of the "sensibus" of 1560.

by parents, are to be traced &632 to monsters. But if you trace them to kinds, there will be kinds totally without limit.

There is also another piece of evidence, since we see flies in Italy, Germany, India, and Ethiopia and other regions so widely separated, flies generated[29] from matter so diverse, yet alike in form and way of life. But if that power were not in heaven, and diverse species were being generated from diverse matter, there would be nearly as many kinds of fly as there are flies. It has been shown elsewhere that things generated from putrid matter can be propagated forever.

Then it has already been shown what animals are of different kind, and which are simply defective and deserve to be called monsters. We are still to show that no animal generated from decay gets tame, but all such creatures are quite wild. This originally occurred because (as has been said), they have weak internal senses; those that do get tame should possess a power of imagination and a noticeable memory, being bloodless; this makes them timid; fear, as we will explain later, obstructs their being tame. They are also mostly short-lived; animals that need to grow tame require time. Lastly, no trace of this tameness or familiarity[30] is taken over from the parents, which helps a great deal in suggesting the animals we wish to tame—we will explain this later. And if this is relevant: since all such creatures are of foul and repulsive appearance, no one will wish for familiarity with these, even if he hoped to be able to achieve his intention.

But some &633 of these are clearly of use to us, such as bees, which we are compelled to handle because of the benefit. Yet they are rather insects than things generated from putrid matter. [A] Some insects can fly, as bees and flies do; others, such as worms and lizards, live in the ground; others like ants are of unclear kind; others live in water, like centipedes; others fly and yet live in water, like river spiders; others live in water and on land, like crocodiles. Of them all, three kinds are the most distinguished: snakes on account of their size, bees and silkworms on account of the work they do. That snakes grow to a huge size is vouched for by the occurrence when Marcus Attilius Regulus at the river Bagrada[31] in Africa killed one 120 feet long with artillery. And in the time of the Emperor Claudius, a baby was found unharmed in the stomach of a boa when it was killed. Snakes of this kind are nourished with milk, and suckle from

[29] The context requires "genitas" here, though 1554 and 1560 read "genitis."

[30] "consuetudo."

[31] Now the river Medjerda, in Tunis. The tale of how the Roman army under Marcus Atilius Regulus successfully engaged a serpent 120 feet long there is in Aulus Gellius (*Attic Nights*, 7. 3; Loeb 2: 101).

lactating cows. People say too that there are dragons[32] which suck out the whole of an elephant and kill it.[33]

In Calicut[34] in eastern India too there are animals like snakes, that is, in their mouth, eyes, long tail; no hairs, the size of boars, sometimes with rather a huge head, but they have four legs, and no poison. In the island Hispaniola[35] in the West Indies, people eat others like these, called Hyuana,[36] with a spiky back, voiceless, four legs, the tail of lizards, very sharp teeth, bigger than rabbits, like hares in size, living in trees, on the ground, and in water without distinction; enduring hunger for many days, their skin marked with various colours and smooth, like the rest of the snakes, &634 high stomach[37] as is the case with birds, but very wide from the chin to the chest.

There are also what are called Bardati,[38] from their resemblance to boss-wearing horses;[39] they are of the tortoise kind, nice to taste, the size of a rabbit, white in colour, and marked with ashy grey; they normally live in burrows in the earth which they dig with their paws. They have four legs, skin and tail like a snake; the West Indies produces these, near the same island. In golden Castile[40] vipers are frequent, twenty feet long, the head as big as a kid's. And in the kingdom of Senega[41] there are snakes of remarkable size without legs and wings, and others are found like the Boas we mentioned. Sumatra[42] produces larger ones.[43] Once upon a time, the Epidaurians used to feed very large serpents, and tamed

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[32] "dracones."

[33] Pliny, *Nat. Hist.* 8. 12. 34: there the "dracones" are so large that "they can hold the whole of an elephant's blood, and so they drink the elephants dry, and these when drained collapse in a heap and the serpents, being intoxicated, are crushed by them and die with them."

[34] Calicut: see n. at 538 (1560) in Book VIII. The animal here might be the garial, resembling a crocodile, but can grow much larger than a boar, up to 6 metres long (*Wikipedia*).

[35] See n. to 127 (1560) in Book II.

[36] Probably the iguana.

[37] "venter supremus."

[38] "Bardato" means "caparisoned" or "bedizened" and is the Italian word for the armadillo (armadillo is the Spanish word). See http://www.uni-mannheim.de/mateo/camenaref/jonston/vol4/books/jonston4_3.xml accessed on 21 Mar. 2008.

[39] "phaleratorum equorum." The remark about being of the tortoise kind first appears in 1560.

[40] "golden Castile" is clearly in Central America, not in the Iberian Peninsula; see for instance Camden, *Annales*, year 1598, 491.

[41] See n. to 576 (1560) in Book VIII.

[42] "Taprobana."

[43] The remainder of this paragraph appears first in 1554.

them—hence too the tale of Alexander, in Lucian.[44] And the Romans were given over to superstition, since a snake lay hidden in the statue of Aesculapius. This kind of snake is in the habit of lying hidden, and can do it for a long time, since it is satisfied with little food, because of the narrowness of its bowels, its scanty native heat, and the dryness of its temperament. The mountebanks know this, and carry them round in a wooden box, and very comfortably with a little bran put in.

But the reason for the snakes' size is the region's heat, since snakes have tough flesh, which enables them to grow huge. Trees too grow a great deal, because they are more compact in substance—elephants are like this too. Their cold nature used to hinder snakes, so that only in the hottest regions can they reach such a size. &635 But those that cannot grow with the help of heat have to be of a very dry nature, and hence very destructive. People say that the regulus or basilisk[45] can kill people with either its voice[46] or its glance alone. If this is so, it is necessary for each spirit to be imbued with air, because the image that it sends with the help of light cannot have a share of venom.[47] Women can spoil mirrors during their menstruation; in the same way, people and animals can be affected by the voice or glance of snakes. It is noticeable that serpents and snakes

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[44] Lucian of Samosata (born about A.D. 120) wrote (*Alexandros oder der Lügenprophet*, 7, 10) on Alexander of Abonoteichus (ca. 150 A.D.) in remote Paphlagonia in Asia Minor, who was a false priest of Asclepius, and that people saw huge snakes so tame and gentle that they were kept by women as house animals, and slept with the children; they were safe even if trodden on, and suckled from the breast like children, and were used as guard animals. He also reported a case of a composer of dubious and oblique oracles being killed by snake bite, and other instances of intervention by a fake snake in bogus prophetic exercises.

[45] These names for the mythical creature really mean the same: "regulus" in Latin and βασιλίσκος in Greek both mean "little king."

[46] The alarming account of this creature by Isidore (*Etymologiae*, 12) replaces Cardano's "voice" with "smell." For its text and much other information see R. McN. Alexander, "The Evolution of the Basilisk," *Greece and Rome*, 2nd ser. 10 (1963): 170–81.

[47] What spirits?—the context here means that there are two that have to be imbued with air. Jean Fernel, a contemporary of Cardano, wrote in his *Physiologia* (Book 4, chap. 7 (9A), trans. Forrester and Henry, 297) that "there are, besides the innate spirits which are permanently lodged in each part, three more wandering ones that pour in: one is the natural one that is dispersed from the liver along the veins to the limits of the body; another, the vital one continuously ejected by the heart through the arteries; and a third, the animal one, generated in the cerebral ventricles, that travels from there through the nerves to refresh the parts with sensory and motor powers." This is orthodox enough, and Alexander (see n. 44 above) reminds us that what killed was not *seeing* a basilisk but *being seen* by one; the traffic was from the beast to the victim. So perhaps Cardano's two spirits were the vital and the animal. In Grafton's fine phrase, "*spiritus* was the super-glue of the Renaissance magician's cosmos" (*Cardano's Cosmos*, 162).

and creatures in which venom is present do not live or lurk in clover, because this herb is deadly to them, as they are deadly to other creatures, and so it is conveniently sown in the hotter places. Vipers too that live in water retain little or no venom—they cannot in fact be dry. But venom either is excess dryness[48] or is linked to it. So not all snakes are venomous, and likewise not all animals that are venomous are crawlers. The scorpions and toads and spiders and some kinds of crab in the West Indies, and some ants lack [510]venom, though they have legs, while wasps and many other creatures do not.

Within the spider kind, nothing is more marvellous than what is called the Tarantula, which captures those it has bitten by their dying from torpor. Relief through music is well known,[49] because it stimulates victims to dance; the dancing dispels the lassitude, and along with it the poison, which is by nature very cold. From Plato's account in the *Phaedo*, Socrates was put at rest by the appointed executioner, so that hemlock would have the power to kill &636 him.[50] So it is not music but exertion that disperses poison, and the tarantula's victims are stimulated to exertion by diverse kinds of music. That sort of poison in fact withdraws the spirits into the interior, and the spirits are stimulated naturally by music, as occurs in horses, boys, and idiots—so they are doubly helped by it.

Why then is it that nature has given poison to so few animals with legs, and not much of it either? It is because if they were strong on legs, they would be too destructive, and so nature has begotten them as slow and small creatures. A spider in the West Indies grows to the size of a sparrow, because by nature this animal (as I said)[51] is cold, which we have also explained with the help of poison. But at the places where it is larger, it is less poisonous. For this reason nature has made no poisonous bird; or if it has, or will make one, its poison will be weak, as is that of the wasp, or it will not be a large or long-lived bird, or it will be rare and small, or will live in deserts. So it is clear why snakes lack wings and legs.

But this is a point in conclusion: is the particular principle[52] being sought? We said that creatures with venom are excessively dry, and so nature has involved

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[48] Scaliger (*Exercitatio* 184(2) [606]) protests that fire, which is very dry, destroys poisons, and gives many other reasons for contesting Cardano's view here and immediately afterwards.

[49] 1550 and 1554 (not 1560) include here a remark that loud music like trumpeting may help, by denying sleep.

[50] What the executioner said (Plato, *Phaedo*, 117A) was, "Just drink it, and then walk about until you feel a weight in your legs, and then lie down. Then it will act of its own accord" (*Plato: The Last Days of Socrates*, trans. H. Tredennick [London: Penguin Books, 1959])

[51] The passage where Cardano states that a sparrow or a spider or a tarantula is cold has not been found in the present work. But he has just remarked that poison is by nature cold, which evidently accounts for his remark that he explains their coldness "by the help of" poison.

[52] "ratio."

horns and claws and bones in their flesh, and has not embellished them with feathers, thus shaping a drier body. Accordingly, snake dung as a rule smells good, and so does that of the huge lizards called crocodilian lizards — they are as big as a crocodile, and of similar shape, and are in the West Indies, and also elsewhere, but rarely come into being at any distance from there. Indeed, the dung of snakes that have a cup painted, as it were, on their &637 forehead[53] smells very good; the good smell, as I said, proceeds from dryness — but snakes, as I said, are dry by nature, and so their dung is excellently concocted because of the narrowness of their bowels, and smells well for that reason.[54] Also, the leaders of vipers living under oak trees are regarded as of this kind; they are said to carry a white crest like a crown on their head. They abound in the recesses of part-burnt[55] homes, even among the most distant Sarmatians, so much so as to terrify new occupants of them. Olaus Magnus[56] mentions that snakes spew out venom of diverse colours, and when he was a boy, his clothing was stained with this, and that naked people are not touched by them.

There are some too whose breath can be smelled so far off that it resembles musk — these are in East India between Calicut[57] and Canonor.[58] There is the same reason twice over, why their breath smells of dung.[59]

There are others there, extremely disastrous, which kill on the spot, and these are called "Mandali." In addition, they are of the viper kind, since we call the most disastrous snakes vipers. Outstanding in this kind are those with a wide hollow head in the outline of a rhombus, lively eyes, and just two teeth (canine ones), a claw in the nose or the tail; tail short, body short, of a lurid colour; onslaught and movement rapid, and head erect. Since the venom of this sort

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[53] The mark on the back of a cobra's hood is well known but is generally likened to a pair of spectacles. It is possible that the cobra is the snake in Cardano's mind, and that the spectacle mark for him resembled a drinking vessel with a ring-shaped handle on either side.

[54] The rest of this paragraph appears first in 1560, and subsequent material up to [B] on 638 (1560) first appears in 1554.

[55] "Ambustarum."

[56] Olaus Magnus (1490–1557) was the last Roman Catholic archbishop of Uppsala, in Sweden, and when exiled to Italy became a distinguished cartographer, and wrote a celebrated *Description of the Northern Peoples*. In book 21, chaps. 47–48, he writes that snake venoms "cause as many convulsions as they contain colours," and that adders spat at him as a boy, and that snakes never hurt an individual who is sleeping naked (in this following Isidore, *Etymologiae*, 12. 4. 48).

[57] Calicut: see n. at 538 (1560) in Book VIII.

[58] About 100 km north of Calicut.

[59] "Duplici autem ratione eadem, quae stercus spiritus redolet." This is very obscure. I read "quare" instead of "quae" and then suppose that the idea is that their dung smells sweet, as some snake dung has already been said to do, and musky, and their breath has picked up the dung smell.

passes across into dead specimens too, they have flesh suitable for the composition of theriac.[60]

There are some venomous creatures that in fact lose their venom at death, such as rabid dogs, and scorpions; some keep it, such as vipers; and their flesh could &638 do no other good in theriac if they were entirely free of venom. What is the source of that notorious skin-peeling[61] in elephantiasis[62] through eating vipers if none of their virtue is preserved in them? Some people have perished while flaying oxen that had been killed by an animal's venom and had swollen up—these people were seized by a similar disease, but some escaped with enormous effort. It seems that this contagion makes its way down to rotting corpses. But in vipers there is another reason: the venom remains in potentiality, because of the powerful dryness, so that you can handle them when dead with impunity—but not eat them. In some creatures only a part of the flesh is concerned with the venom, not all of it—for instance the sting in scorpions, the teeth in dogs; these lose their venom on death.

And vipers become worse in response to the region, as in Numidia, where they are both fiercer and more destructive, and the scorpions likewise—just as mountain ones are worse than wood ones. Others become worse in response to food, for instance those that eat the red frogs called toads; their blood is affected by the food, and then their limbs. But above all their saliva becomes unhealthy, and hence a method has been found to taint arrows with poison—the teeth are used for tips of arrows. [B] Through aridity,[63] their dry skin is shed by vipers, and this is called the slough[64]—what[65] happens to them is what happens to human beings suffering from elephantiasis, that is, that from the vapour of corrupt humour, the skin dries and is shed. Consequently they shed it in spring, dried up by their long fast, as cats do; hunger dries up the body and corrupts the humours, and they start the shedding from the head.

Since the natural practice of vipers resembles the preternatural case of &639 elephantiasis sufferers, viper flesh must be of help to patients with elephantiasis, just as when epileptics are helped by passing through them the bile of asses

[60] A medicament with a great and inconstant set of constituents, supposed to be effective against poisons and venoms of all kinds. See n. in Book II at 93 (1560).

[61] "excoriatio."

[62] Fernel, a contemporary of Cardano, describes how this condition affects the skin very severely, with pustules and ulcers and total loss of hair. See Forrester and Henry, *Jean Fernel's On the Hidden Causes of Things*, 627–29.

[63] "siccitas."

[64] "senecta."

[65] The rest of the sentence and the following two sentences appear first in 1560.

or deer.[66] If the eyes are rubbed each morning with a snake's slough,[67] people say that they [the people] are not impaired at all by blunting of vision, or by cataract.[68] But while less true, yet it is more remarkable that if the shed skin is cremated while the Moon full of lights is in the first portion of the Ram,[69] and the collected ash is scattered upon the patient's head, terrifying dreams are dispersed. If one's face is washed in this diluted with water, one looks terrifying; if it is held under the tongue, one seems wise and eloquent; if it is placed under the sole of the foot, one is viewed with favour by princes and the magistracy. All snakes too that either have a claw on their tail or a horn on their forehead are excessively dry, and consequently very deadly. So for snakes to possess venom, they had to do without hair, feathers, legs and other items,[70] and they have little need to drink, and to have red eyes.

[511]For this reason almost no fishes are venomous, but if they are in a very dry part, there are some like that, such as sea slugs[71] with bile, and weever fish[72] with spines. Further, there are wasps with a sting, which is their driest part. This shows how much damage they could wreak on the rest of the animals, if snakes predominated in running or flight,[73] because apart from the tiger hardly any animal was so rapacious and speedy. And people can hardly inhabit regions where darter snakes[74] climb up the trees. Snakes,[75] just like fish, possess many diverse forms, so that people of our times, taking advantage of the variety, have dared to display a snake with &640 two legs and seven heads—as is written in the Apocalypse:[76] the middle head longer and thicker, the rest, being equally

[66] "sicut comitialibus asinorum, cervorum bile perfusis"—translation speculative. Pliny mentions dosing epileptics with bile, though not with that of donkeys or deer. He suggests lion's bile (*Nat. Hist.* 28. 25), which may be mingled with its fat, and the patient should go running afterwards to facilitate digestion; bull's bile (*Nat. Hist.* 28. 63); and sheep's bile (*Nat. Hist.* 30. 27).

[67] "senecta."

[68] "suffusio."

[69] A sign of the Zodiac, Aries.

[70] As Scaliger acidly remarks: "Why not then scales too?" (*Exercitatio* 189(2) [620]).

[71] "lepus marinus," *Aplysia depilans*. Pliny (*Nat. Hist.* 9. 155; Loeb 3: 269) says that it "infects even by its touch, immediately causing vomiting and laxity of the stomach, and in our own seas the shapeless lump resembling a hare in colour only."

[72] "aranei pisces"; Pliny (*Nat. Hist.* 9. 155; Loeb 3: 269) says these wound with the sharp point of their dorsal fin.

[73] "volatu."

[74] "iaculi"; Pliny (*Nat. Hist.* 8. 85; Loeb 3: 63) says that they hurl themselves from trees.

[75] The passage to [C] on 645 (1560) appears first in 1554.

[76] The Apocalypse of St John the Divine, i.e. the book of Revelation in the Bible; but although at 12: 3 and elsewhere there is a "draco" with seven heads, there is no mention

distant from it, matched and equal; as they receded further from it, their necks were thinner and shorter. The heads were vipers' heads, the eyes behind the ears, the gape huge, the teeth very like dog teeth, but thinner, the front ones small, with those at the sides longer; the tongue broad like a human one, and the head like a human head; the skin very hard, unbroken, with cartilaginous spikes as though in a patchy sturgeon.[77] Necks separated from each other were projecting from the body. The tail half as long again as the whole body, like the tail of snakes. Legs small, with long claws; the size of a rabbit; white under the stomach, on the back exactly lemon-coloured—that is, dilute green, mixed with the colour of chaff.[78] They used to add live ones they had found, and of both sexes; but when I thought it was a fabrication, reasoning that two principles could not be present in an animal of the same kind,[79] much less more of them, and that the hydra was fictitious, that learned man Ioannes Meona of Pisa[80] explained the whole thing to me. I mean,[81] that this monster had been dissected at Mantua, and a fiction had been devised. Though I do not know what greater miracle could be mentioned, whether as produced by nature or as so aptly contrived by art.[82] Such is the power of the accursed hunger for gold.[83] But there is a widespread question whether an animal can have two or more principles; the Salamander is a very well-known animal (and lizards are almost exactly the same), which is found in springs, the interstices of walls,[84] and &641 [wrongly numbered 643] underground. (It is also very frequent in Italy, especially near Padua, where once I saw one while crossing the bed of some streams, looking just as though sprinkled with pebbles.) It was of a patchy sallow colour, with almost a snake's tail—a snake too that barely feels it when close to small fires, and extinguishes them by extruding humour; divided down the middle, with the front part it proceeds forwards and with the back one backwards.[85] This is why it is supposed to possess

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of two legs, though such representations are known in visual art.

[77] The sturgeon (*Acipenser sturio*) has rows of bony platelets on its sides, which may explain the adjective "patchy" here.

[78] "palearis."

[79] That is, two principles, each involving a head (or heads), cannot coexist in one body; this becomes clearer later.

[80] Not otherwise identified.

[81] A reference here in 1554 to the source being the counsels of Don Ferrando Gonzaga is absent in 1560.

[82] The syntax is obscure: "Quanquam nescio quodnam maius miraculum dici debeat, an naturae [sic] produxisse, an artis tam apposite finxisse."

[83] "Quid non mortalia pectora cogis, / Auri sacra fames?" Vergil, *Aeneid*, 3. 56–57.

[84] The phrase here is "maceriis murorum," and though "maceria" like "murus" means "a wall," the phrase presumably means for Cardano "in the interstices of walls."

[85] This encounter is first mentioned in 1560. For the amphisbaena see Pliny, *Nat. Hist.* 30.85.

two principles of motion. But clear proof is needed of how an animal can and cannot have two principles of motion.

So there is nothing to stop some monsters being born with two heads, since even boys like that are found too, as we will explain below.[86] What nature does in the case of some human beings, it can bring about in the imperfect kinds. It was shown previously that there are monster-making kinds, born of these animals that are generated from decay. Such creatures are in the likeness of a species,[87] but are not—they are animals maimed by a principle of generation; it is impossible for nature not to function correctly in reference to the system of its purpose, if it is hindered in no way at all. Thus it is a matter of chance for an animal to be found with double head, although it occurs in a number of animals according to the same form; all such animals are generated from the same animals by their kind, and from those that are lacking in the same instrument.[88] But salamanders are not monsters, nor do they possess more than one principle of movement; but when they are split into two parts,[89] they have a very deficient power of imagining. &642 Anything remarkable, since they are of dim power of sensation when in normal health?—I refer to the power of external sensation; what should be said about the internal one? The reason for this mode of progressing is that, though they have a very weak power of imagining, it does instruct them to avoid grief and harm—when their body is cut in two, and one part split from the other, both parts feel pain; so the front one reckons the wound is behind, and the back one reckons it is in front. Hence for both parts to escape pain, the front one will move forward and the back one back. This produces the appearance[90] of an animal possessing two principles of motion. So no animal (other than a monstrous one, imperfect by nature) can possess two heads, both because nature does not do with numerous resources what can be completed with fewer, and because such an animal could disagree and quarrel with itself. These are the persuasive lines of reasoning; the demonstrative ones will be produced in the books *De arcanis aeternitatis.*[91]

But what you will say is: "Crabs move to either side, but have feet facing forward, hence do not move to either side from a principle; if they had a principle of movement to either side, they would have senses on both sides, and thus instruments of movement." These animals are divided by nature, they are right and left, and their senses too are distributed according to the sides—and also to front and rear. Thus they live a split life, and are far from perfect, because they lack much heat. The evidence for this is what Ioannes Leo mentions occurred in Egypt: a

[86] On monsters and explanations of them, see Bates, *Emblematic Monsters.*
[87] "species."
[88] "instrumento," but the meaning is unclear.
[89] "dividuntur."
[90] "species."
[91] See n. 19 above.

man was cut in two by the executioner as a punishment, and with his upper part placed on a hearth[92] where &643 quicklime had been sparingly scattered, he survived for a quarter of an hour, and recognised people and gave replies.[93] So an animal retains sensation everywhere, provided his heat allows it, and also retains every function of which the instrument has not perished. This is how to settle so many arguments of folk who cannot accept that an animal can live without a head, and of others that one can live without a heart; without a head they cannot feel, but are alive; without a heart they do feel, but their heat and movement and life runs out very quickly. So if any animal is split in two, its sensation lasts provided its heat stays warm.[94] But insects, which need little heat, live and move and do their imperfect imagining as long as life or the vital heat persists. Also their power of imagining the future, as well as their sense of the present.[95] Thus by avoiding pain (this concerns the future), the parts of a salamander move in different directions, as is said.

But to return to my plan: that mountebank[96] showed another snake, which he called a "dragon," half the size of the previous one. Possessing two lower limbs, [512]it had devoured aged legs,[97] it had a neck and a head like a snake's. It had two small cartilaginous wings like a bat, and because of the poor quality of these wings, I would not believe that it was going to fly, even if it were alive.[98] However, there should be no doubt that there was a dragon fish, but one described as of another kind, with inserted legs;[99] we have seen a real dragon when with our friends the Madii, with a long tail and neck; on the neck there were twin spines on the other side,[100] and on the tail the same number of feathers, or rather spines;

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[92] "focus."

[93] A murderer was cut in two by the executioner, and the upper part "is put into a fire full of unslaked lime: and it is a most strange and dreadfull thing to consider, howe the same dismembred and halfe body will remaine aliue in the fire for the space of a quarter of an hower, speaking and making answer vnto the standers by" (Leo Africanus, *History and Description of Africa*, trans. Pory, 3: 887).

[94] "fervetur."

[95] This is not a complete sentence in the Latin either.

[96] Apollonius of Tyana, presumably—see n. at 623 (1560) in Book VIII—but the tale has not been found in Philostratus. Or perhaps one of the "people of our times" mentioned above at 639 foot (1560).

[97] "pedes vetustas exederat"—probably "had created ulcers on aged legs."

[98] The remainder of this paragraph and about half the next first appear in 1560.

[99] There was, and is, a "dragon fish": *Trachinus draco*, also *Trachinus araneus*, known also as "weever fish" (and see n. 72 above), with a nasty stinging spine on top. For full details of this fish, and references to Pliny and other authors, see D'Arcy Thompson, *Glossary of Greek Fishes* (Oxford: Oxford University Press, 1947), 56–57; but there is no mention of "inserted legs" there, and the identification remains uncertain.

[100] "altrinsecus"; probably "on each side" ("utrinque," a word Cardano uses on 646 [1560], for instance) is meant.

these and all others were like the teeth of a small puppy. They were arranged on the tail in &644 triple rank, sixty in number. And some between the wings and on the back, and before the start of the tail individual ones on both sides. Sizeable wings of membrane, like those of bats; it was like the skin of an angel shark,[101] with which its whole body was covered. Head small, and with the same membrane, along with the whole spine, but provided with a sort of beak.

But on its head was what resembled a sort of felt cap. Mouth wide and fully open; lips thickened with bony granules. Canine teeth twinned on both sides: the one in fact on the upper jaw and the other on the lower. Middle teeth as in dogs, quite short. Individual molars on the upper jaw on each side had a place on the lower part of the twin tongue, and I do not think the tongue was eaten away. The eye spaces very wide. But that mountebank[102] also had two live snakes, which were of the viper kind, two cubits[103] long, with a purple tail, shiny and sallow, claw or horn at the nose tip, bent upward—the rest the usual viper head, eyes and teeth.

In my hands I have another one almost like this and almost free of any suspicion of being contrived by artifice—but there were no wings—it was found in recesses of a demolished house in Milan. Head the size of an egg, and very large in relation to the body. I have kept by me a bone from it. Teeth like vipers' teeth in both jaws; body the size of a gecko, and of similar form. But only two lower limbs,[104] and short lower legs, so that it is apparent that it was not sufficiently conveniently constructed by nature, since for such a length four legs would have &645 been needed—but they are large, and with big claws, such as cats have. The tail equals the length of the whole animal; on its end a knob is present equal in size to the head of an Italian gecko, and virtually rounded. I could believe that this belonged to the kind of basilisks; when it was standing up it could look like a cock, apart from being covered with skin, not feathers, and having no wings.

[C] But let us leave these behind and return to the kind of bees. They are generated by propagation, and from the decay not just of anything, but of oxen,[105] as wasps are generated from horses, drones[106] from donkeys, and hornets from mules. Hence when individual items decay, they appear to generate some appro-

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[101] "squatina"—see Pliny (*Nat. Hist.* 32. 150) and also note that the name is now the official name of the angel sharks and related species. For full details and references on this shark, see D'Arcy Thompson, *Greek Fishes*, 221–22.

[102] See n. 96 above.

[103] A cubit is the distance from the elbow to the finger tips, i.e. about 45 cm.

[104] "pedes."

[105] At 608 (1560) bees are said to be produced from honey they have themselves polluted—and also from the corpse of a calf; the latter appears in the *Georgics* quotation below.

[106] "fuci."

priate kind of animal. A worm[107] arises from nightshade leaves[108] and is then in a jasmine plant—it is marked with a green and chaff-like colour, of a circumference less than a thumb, longer than a palm,[109] green in the up-facing part, with three black legs on each side near the head. Under its stomach it has a set of four apophyses on each side,[110] which it uses instead of hands to attach itself securely.

In place of a tail, it bears a horn of this shape and size, of a yellowish colour, scattered with white granules. But strange to say, this vanishes when the animal wastes away, and then it carries nine black patches on both its sides, mimicking that number of holes so well that a needle would be required to reveal the deception. A thin dark beak, with two hook-like features on each side, and with it it consumes so much of jasmine leaves each day that their weight would equal that of the worm. The result is that it actually expels a little less dung, which is without odour, dark, smooth, rounded, striped, of a thickness almost the worm's. The female has no hook on its &646 [wrongly numbered 546] tail, and dark patches on both sides of its head. Like the other members of its kind, it passes over into a dusty silkworm nymph[111] of an ashy colour, the biggest of its kind, and sluggish in its habits. [D] The willow also has its bedbugs,[112] and rue has deadly little worms; the poplar has another one, and the fir tree another still. And so Vergil is found to have sung about the origin of bees:

> Then a bullock is sought, one just arching his horns on a brow of two summers' growth. Struggle as he will, both his nostrils are stopped up, and the breath of his mouth; then he is beaten to death, and his flesh is pounded to a pulp through the unbroken hide. As thus he lies, they leave him in his prison, and strew beneath his sides broken boughs, thyme, and fresh cassia. This is done when the zephyrs begin to stir the waves, before ever the meadows blush with their fresh hues, before the chattering swallow hangs her nest from the rafters. Meantime the moisture, warming in the softened bones, ferments, and creatures of wondrous wise to view, footless at first, soon with buzzing wings as well, swarm together, and more and more essay the light air, until, like a shower pouring from summer clouds, they burst forth, or like arrows from the string's rebound, when the light-armed Parthians enter on the opening battle.[113]

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[107] The worm's description in 1554 is very much expanded in 1560.

[108] The passage to [D] on 646 (1560) first appears in 1554.

[109] On the dimensions of a palm, see n. at 1080 (1560) in Book XVII.

[110] See n. 100 above.

[111] "necydallus."

[112] "cimices."

[113] *Georgics*, 4. 299–314; Loeb 241. The text as printed by Cardano differs only slightly from the Loeb text: Loeb prints "tunsa" ("pounded") instead of Cardano's "tonsa" ("shorn"), and "sagittae" in the penultimate line instead of Cardano's "sagitta."

But although Aristotle is uncertain enough about their generation, it is established that neither honey nor beeswax could be generated from any other animal;[114] honey necessarily needs to be generated from thin moistness mixed with fattiness with dew. So they ought to be small animals which would settle—flying animals, that would return quickly, &647 that would collect a great deal that is very small—earnest animals, that would complete a task quickly. But such creatures could not incubate an egg, and so bees are generated from honey. This kind also thrives in very cold regions through a wise device of nature: they hibernate in winter. And so in Muscovy there is an abundance of honey and beeswax, enough to bring them into contempt. The long duration of the day compensates for the region's cold; it is eighteen and more hours long.[115]

The way in which in a hotter climate silkworms are generated is no different from the way in which bees are generated from oxen. Evidently Aristotle knew this—[513]he does say, "Pamphyla the daughter of Plates in the island of Cos first taught how to weave silk garments from thread made by a silkworm."[116] This animal is born originally from a worm of its own kind, which has horns; then from that there comes a caterpillar,[117] and afterwards a silkworm; then a silkworm nymph, the whole conversion being completed in six months. It is like a butterfly, but produces eggs from the copulation[118] of male and female. And meantime it eats nothing, but with the eggs produced, it wastes away.[119] It does not fly, except to seem to imitate a jump. And it is extraordinary how when this became known long ago, silk[120] clothing reached such a high price.

Procopius recounts that monks imported the eggs of some worms from the city of Serinda in India[121] during the reign of the Emperor Justinian (and thus

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[114] But Scaliger (*Exercitatio* 191 [623]) has read that there is a fly in the Moluccas that makes honey in the trees.

[115] 1550 perhaps puts this sentence better, indicating that a *summer* day is meant.

[116] "The first to do this weaving is said to have been a woman of Cos named Pamphile, daughter of Plates" (Aristotle, *Hist. animal.* 5. 19; 551b16–17; Loeb 2: 177). Peck remarks in his footnote there that this cannot be a reference to the silkworm, since it is thought that it did not come into Greece until the middle of the sixth century A.D., and he presents further evidence on this point.

[117] "eruca", the orthodox classical spelling of this word with the meaning "caterpillar" is "uruca" (*OLD*).

[118] Reading "congressu" with 1554 and not the "congressi" of 1560.

[119] The Latin is confusing—"ova *edit* congressi masculi foeminaque: nec *edit* interim quicquam, sed ovis editis tabescit."—until it is realised that there are two verbs "edo," one meaning "to produce or give forth," the other meaning "to eat."

[120] "sericea"—i.e. from China.

[121] It was not a city, but a country north of India. Procopius (*History of the Wars*, 8. 17; Loeb 5: 229) wrote that the Romans (i.e. Byzantines) wished to produce silk themselves, instead of importing it; so certain monks from India came to the Emperor Justinian claiming to have spent long in "Serinda" and to have learnt the method; "certain

about 840 years after Aristotle), and Vergil says, "The Chinese are known by their fleece, not by their face."[122] And elsewhere, "The Chinese comb off thin fleeces with leaves."[123] And Pliny: "The Chinese are celebrated for the wool found in their forests; they soak it in water, and comb off a white deposit on the boughs."[124] I think, however, that this silk of ours is the famous one celebrated by the &648 ancients, and known to Aristotle (as I said), but the threads were conveyed from India, accompanied by a definite plan for feeding them, with the tradition,[125] or what Pamphila[126] taught, extinct, and people weave them after their recognition through Alexander the Great's victory, but not with import of the worms.

Thus it was under Justinian that both the eggs and the art of rearing them reached us through the monks. Meantime, while they remained forgotten, the ancients were convinced that they were combed out of a deposit on boughs of trees—either this seemed more likely, or because silkworms emerge there spontaneously in woods, or because in this way the inhabitants hoped better to be able to conceal the origin of silk. But thanks to this Emperor and his maternal uncle, the whole world got to know, and it became common knowledge that there is no other kind of silk except this Chinese kind. Thus silkworms are exceedingly useful, in next place to bees.

Nowadays animals[127] are brought to us for creating a purple coloured silk, animals looking like bedbugs with their heads removed, and because of them the price for red silk has been halved, since at one time it was made from little worms growing on the root of the herb bibinella.[128] And there are animals which are transported, and are gathered from bibinella; the evidence is foul fat on the bibinella,[129] and quite foul fat on the worms. This matter is fatty, so as to stick tightly, and is blood-coloured, so as to retain a vivid colour; the purple colour once used to be extracted from an animal. But the little worms arise from bibinella in Germany, and are mixed with butter, in such a way that you could make

worms are the manufacturers of silk, nature being their teacher and compelling them to work continually. And while it was impossible to convey the worms [to Byzantium] alive, it was still practicable and altogether easy to convey their offspring. Now the offspring of these worms, they said, consisted of innumerable eggs from each one."

[122] "Ignoti facie, sed noti vellere Seres." Reading "non et . . ." instead of "noti," Isidore, *Etymologiae* 9. 2. 40 quotes this.

[123] Vergil (*Georgics* 2. 121) wrote, "velleraque ut foliis depectant tenuia Seres," and this I have translated. But Cardano writes here, "foliis depectunt vellere Seres."

[124] Pliny, *Nat. Hist.* 6. 54.

[125] "disciplina."

[126] For Pamphile (or Pamphila) see n. 116 above.

[127] 1550 and 1554 have "semina" here, not "animalia."

[128] A name for Salad burnet, *Sanguisorba minor*, or alternatively another herb, *Pimpinella saxifraga*. The remainder of this paragraph appears first in 1560.

[129] Reading "in bibinella" for the "in bibinellae" of 1560.

out nothing except rotting filth. But a fat thing preserves the colour for another fat thing, while the substance is decaying. Four pounds &649 of this matter are needed for each pound of silk—or of the Indian kind barely half a pound, bcause it is pure and dry, and so its colour is less clinging and vivid. But if it were preserved by some fat matter, undoubtedly the colour would be rendered brighter and longer-lasting; it is actually inevitable that along with the useless moistness something of use vanishes. Many items are commonly added while this purple is being made, so discerning is the human pursuit of profit—and among the rest, arsenic, alum, wine-lees, ben-nut gall,[130] zedoaria,[131] soap froth, and bran cream.

Contrariwise, locusts appear to have been provided to the detriment of the human race; they are not plentiful everywhere, this plague being practically confined to Africa[132]—and what is more remarkable, it does its work almost entirely on alternate years. For a wonder,[133] the locusts cover the sky just like a thick cloud. Regions on which this disaster has descended are devastated in their crops and in every shoot in a single night—you might say that snow had fallen all night long, if they were as shiny white as they are in fact dark. Their form is like that of Italian locusts, but of a dim red colour, a little larger, and with the faculty of flight. Some people think that in view of their abundance and the distance from their region, they are carried to us over the sea by the winds, not of their own efforts. They are generated close to marshes, and while they are flying into cultivated African land, they do not generate, or very little. Those that are left behind in the marshes cannot multiply so much, so they have to fly out for food, but rest content with brushwood[134] and marsh weed. The result is that they &650 invade a province as a rule only in alternate years, and rather rarely too, for the most part. Those that leave when the crops have been consumed, being compelled to fly out to seek food, end up hurled into the sea by the winds. Sometimes when the winds are persistent and the locusts strong, they are driven right to the regions facing Africa, a misfortune not unknown in Sicily and later in Italy.[135] In 1543, we saw them in Italy; they visited the farmland of Turin, a more unlucky possibility than any loss. That region over the subsequent fifteen years is being laid waste by endless war, although previously it had been in distress for seven other years. From the first hour till the sixth, the passing squadrons blocked off the Sun the whole time. Experience shows that effort to destroy the eggs by fire is

130 "galla mirobalani"; the word is normally spelled "myrobalanum" and is so spelled at 555 (1560) in Book VIII.

131 *Curcuma zedoaria* is the "Hidden Lily Ginger" of present-day botany.

132 Scaliger (*Exercitatio* 192 [625]) vigorously contests this statement.

133 1554 mentions that Cardano saw this in Italy not long previously; 1560 does not.

134 "sarmentis."

135 The following three sentences here were first introduced in 1560.

worth while, because they are deprived of offspring.[136] But if effort is not applied, this disaster is found to rekindle the following year, with great trouble—in addition to the inevitable infertility, there is also a chance of plague being introduced, and a presage of war to come.

However,[137] they are of use to some people; nothing from each direction is either so fortunate or so unwelcome[138]—the Arabs and the Libyan peoples make the locusts dried by the Sun into bread; they also eat fresh ones. No wonder—since Moses, very industrious at selecting food, permitted the Hebrews to eat locusts, as being healthy.[139] And John the Baptist used to feed on them in the desert, along with wild honey.[140] People without experience of the nature of things and ignorant of it marvel at this, and make up many ill-conceived tales, that a lone man could not eat locusts in the desert—although some German soldiers, well supplied with resources, fried and ate as &651 a treat the silkworms we had nurtured in hope of silk—and rightly, for things that are harmless are also free of foul taste and smell, and are only supposed to have them.[141] The Italians actually eat burbots,[142] which differ from worms only in colour, since the burbots are dark-coloured, but the worms red—and they reckon them as delicacies, although they are generated like locusts and silkworms from decay, not from eggs. On a similar basis we eat oysters and shellfish so eagerly that we even devour them raw, oysters and shellfish which we know are created from decay. Beyond these three, I know of no animal taking origin from putrid matter alone that is in culinary use. The Germans detest frogs (which are fish with a voice),[143] but our people [514]eat without hesitation those that resemble toads, and are revolting on their appearance alone, and from their resemblance to toads dangerous as well—such power does custom have in all cases. There is however nothing remarkable in making bread from locusts; when dry, they pass over conveniently into flour, and have a light substance, and contain moist fattiness, which has been stated plainly as a common feature of all animals. So if locusts are milled, pounded, and boiled down,[144] they will be capable of making excellent bread.

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[136] Aristotle (*De Generatione animalium*, 1. 16; *Hist. animal.* 5. 19 confirms) held that locusts were generated sexually, not by spontaneous generation: "Some insects copulate and the offspring are produced from animals of the same name, just as with the sanguinea; such are the locusts . . ." This accords with Cardano's observation here.

[137] This paragraph first appears in 1554.

[138] "adeò nihil ex quaque parte aut beatum, aut ingratum."

[139] Leviticus 11: 22.

[140] Matthew 1: 4; Mark 1: 6.

[141] "sola opinione constant."

[142] "mustelas"; the fish which have gone under this name are reviewed by D'Arcy Thompson (*Greek Fishes*, 38, 168–69, 220), and the identification is not certain.

[143] "ranas canoros pisces."

[144] "decoquantur"; a word indicating baking would have been expected.

I say "excellent," not in its simple sense, but for the regions and people that are rustic and wild, who have nothing good. The moist fattiness is preserved, with the wateriness dried up by the Sun; and no wonder, since it is the kind of moistness that is immune even to fire and does not burn. Otherwise, burnt copperas[145] would not release an oil, but it does, because that moistness is linked to its substance; when an iron bar takes fire, if the &652 whole of its moistness were on fire, the iron would not be extinguished, but the ash would. There is then a kind of oil, a fatty moist one, which does not readily take fire. Such is the moistness of solid metallics, like iron, gold, copperas, mercury.

But although some of them are smaller than bees, why is it that they (I mean ants, butterflies, and locusts) generate eggs, but bees cannot? The reason is that when they lay them, they are not flying, but retain the form of a caterpillar[146] or aurelia,[147] or perish along with these, as do silkworms and locusts; eggs in such tiny animals did impede flight. Since, then, it would be better for bees to be long-lived, because they are so extraordinarily useful, their lives are in fact prolonged into a seventh or even an eighth year, and it became impossible to lay eggs. And we should accept that not just such tiny creatures but also larger animals—indeed, all animals—derived their origin from decay, since it is agreed that mice and fresh-water fish are spontaneously generated. Since, as I said, the decay has come first, the fattiness is separated from the ash, and the heat at once pours into a soul suited to that matter. This is why all animals that are generated from putrid matter (such as moths and worms and woodlice) put a limit on pains originating everywhere, apart from anything else they do—they actually come from very hot and moist matter. It is therefore not remarkable if cantharides do not do this—they are actually generated from eggs. Instead of these powers, they have others: in moderate dosage they produce sexual excitement,[148] and very large penile erection; in larger dose they ulcerate the bladder and produce blood in the urine; &653 in still larger dose, they render people mad.

In the same way, the fire-flies[149] (λαμπυρίς in Greek), which Italy produces, the size of flies but thinner and comparably longer, flying and glittering on summer nights, with six legs, wings harder than flies, are actually of the hornet kind, with very white entrails, the outer skin polished so well that it shines during life—so that in the gloom at times I could read written letters as if I had the help of a candle—they change over from caterpillar into glow-worms, or (as is actually more probable) from glow-worms into caterpillars. Since the caterpillar is

[145] "calchantum"; see n. to Book II at 131 (1560).

[146] See n. 117 above.

[147] This appears to be a stage in insect development, but has not been clearly identified.

[148] "tentigo."

[149] "Cicendulae": the orthodox spelling is "cicindelae."

larger than the glow-worm and shines less, as if worn out at the time by old age, it is probably then that the eggs are laid, not while it is flying.

The lesson of these animals for us is that a liquor can come into being capable of shining in darkness; this is what occurs in the rotting things that have the utmost shiny whiteness, light and translucency. I am sure this can occur, but still not sure from what source, or how. But an explanation[150] can be derived from the jellyfish;[151] when it is smeared on timbers, it makes them glow at night like torches. The cause is moist fattiness, which produces shining, and the power of illumination contained in it; things that glitter, and are not long removed from the action of the celestial heat, shine at night. So this will be the explanation of such occurrences. Consequently the bark of oaks, and anything that picks up moist solid fattiness from decay, shines at night like a fire while it rots. Similar are rotten timbers and tree fungus;[152] they are of a strong shiny dry white.

&654 The Cocoyam[153] presents a greater miracle than the glow-worm; Hispaniola[154] in the New World produces this animal, evidently of the beetle kind. Size like that of our beetles which we call "stag beetles," on account of the length of their horns. It flies as much as the glow-worm, and its body shines, but its eyes much more, enough to resemble a candle—they are very large and prominent in comparison to its body size; by their light reading is done, writing is done; the Indians too used to hold parties with their light alone—they contain within themselves such a large and bright light that no greater marvel can be found nor needed. As their life declines, it goes out, and all the life perishes with it, its power is so intimately linked to the vital soul. However, the famous liquid that used to shine stays on in its eyes and stomach, and when they are smeared with it, it makes their skin as reddish and bright as charcoal, either because it still retains some illumination, or because it ignites the skin with its heat.

Marvellous too is the generation of the pyrausta, like the glow-worm's illumination; Aristotle reports that the pyrausta lives among the fires in the furnaces of Cyprus[155]—as he recorded about the red hairy worms in the snows.

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[150] "ratio." The rest of this paragraph was first introduced in 1554.

[151] "*Pulmo marinus*"; it is briefly mentioned by Pliny (*Nat. Hist.* 9. 154, 18. 359, 32. 102), but he does not mention the effect of smearing them on timbers.

[152] "agaricus." This sentence first appears in 1560.

[153] What is now referred to as the Cocoyam (*Colocasia esculenta,* also referred to as Elephant's Ear or Taro Potato) is a vegetable. Identity here unclear.

[154] "Hispana" here; on Hispaniola see n. to Book II at 127 (1560).

[155] There is confusion here. Pliny mentions the *pyrallis*, a creature that exists amid the fires of Cyprus, a characteristic Cardano here associates with the *pyrausta*: "Some creatures are generated also by the opposite natural element. Thus in the copper foundries of Cyprus, even in the middle of the fire there flies a creature with wings and four legs, of the size of a rather large fly; it is called the *pyrallis* or by some the *pyrotocon*. As long as it is in the fire it lives, but when it leaves on a rather long flight, it dies off" (*Nat. Hist.* 11. 119; Loeb 3: 505–7). On the other hand, the *pyrausta* is to be found in Aristotle (*Hist.*

It is also said that the pyrausta is generated in fires,[156] or passes its life in them after being generated elsewhere, which is more likely and should be believed, since fire cannot generate anything. So they are generated from the dross at the bottom of a fire and of snows; worms are very hot and therefore tolerant of great heat—the pyrausta is correspondingly very cold. So the pyrausta is generated from the decay of the most solid moistness &655 of the metals, in an environment close to fire, to prevent the moistness being corrupted by the fire, and is not originated far from it, although when mature it has become intolerant of fire. In similar fashion too, worms are generated in snow, on the condensation of some hot vapours which are enclosed by cold, and they rot, having gathered with them the residue of moistness. This is the way in which the generation of such things takes place, and since they are generated in the utmost cold, it is not surprising that that they are preserved in the same cold, although no cold generates anything. In fact nothing can be generated more in the utmost cold (such as that of snow or ice) than in fire. Everything, then, must be generated by a temperate heat, but the temperament is not the same for everything.[157] It is said that [515]huge worms are born in the mountains of Armenia, which are called "teredines,"[158] and are generated under the snow, and are alleged to contain very pleasant water—so those who capture them burst their outer coat and drink it. Similarly, amid the snow are said to be hollow lumps containing a membrane in which water lies hid which is nice to drink. The authorities for this are Apollonides[159] and Theophanes,[160] in Strabo.[161]

There is also in Cicero the well-known account of the Ephemerus: that an animal with a set of four legs and the same number of wings is born near Hippanis a river of the Bosphorus,[162] and leads its life from morning till evening,

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animalium 7. 27, 605b11; Loeb 11: 195); Balme mentions in his footnote that there the word means a moth: "The wax moth, *Galleria mellonella*, whose cocoon could be confused with the cobweb developed by *Clerus*." Aristotle does also briefly mention the *pyralis* (*Hist. Animalium*, 609a18) and there it is a bird!

[156] Remainder of paragraph expanded considerably and revised after 1550.

[157] Remainder of this paragraph first appears in 1560.

[158] This word in classical Latin means "shipworms" or other small similar creatures.

[159] Little is known of this Apollonides. According to the scholiast on Apollonius Rhodius (4.983, 1175), he wrote a geographical treatise entitled Περίπλους (Periplus).

[160] Theophanes was a historian of Mitylene, who accompanied Pompey in his wars, and wrote probably in 63/2 B.C. (*OCD*).

[161] Strabo, *Geography*, 11. 14. 4: the creatures are for Apollonides σκώληκες and for Theophanes θριπές (woodworms). For Strabo see n. to Book II at 209 (1560).

[162] The river Hypanis (not "Hippanis") is the (southern) Bug, which is not a river of the Bosphorus but in the western Ukraine, and it runs into the Black Sea near the Dnieper estuary. Aristotle (*Hist. animal.* 5. 19; 552b17–23; Loeb 2: 185) wrote, "On the river Hypanis in the Kimmerian Bosphorus, round the time of the summer solstice,

deriving its name from this.[163] It is a boy in the morning, a youth at midday, an old man in the evening, and dies with the setting Sun. Thus &656 nature is seen to expend much more effort and time on generation than on the function of living.[164] So one can legitimately marvel at the great care taken by the foundress,[165] who has endowed such a short-lived animal with so many instruments and faculties. It sees, it hears, it flies, it walks.

Nature has armed the mosquito to our harm; a tiny plentiful animal, so that it can scarcely exist near water in comfort. With a sturdy trunk,[166] so that nature seems to brood over[167] the elephant while begetting this animal; it pierces not just human skin, but horsehide, drinking blood and causing intense pain, finally disturbing sleep on summer nights with extraordinary buzzing, so that nothing could be more abominable. It does not strike while passing by, like flies, which attack everyone indiscriminately, but chooses whom to strike—it fancies only sweet blood. The fly is hated,[168] but is fended off by nets of thread; it is afraid to entangle its wings, and this is sufficiently established by experience. The same plan will be one to follow in fending off midges.

The race of ants too becomes winged as it ages. No[169] wonder, for in Phrygia the scorpions have wings. We too have sometimes been terrified by the touch of a winged scorpion, but it did not prick us, and we came to no harm. This also occurred in Paduan territory near the town of Sacca,[170] in 1527 if I recall aright.

Thus many such creatures, including silkworms (as I said), put forth wings as they age; nature comforts them for their weakness by endowing them with flight. But they do not survive long after the wings have been put forth. Ovid recounts a more extraordinary transformation they undergo, with these words:

> "If you cut off the &657 hollow claws from the sea-shore crab, and bury the remainder in the earth, a scorpion will come forth from the dead crab buried there, threatening with its crooked tail."[171]

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certain objects like wallets, larger than grapes, are brought down by the current; when these break open, a winged four-footed animal emerges; it lives and flies about till evening, and as the sun drops, it pines away and dies at sunset, having lived precisely one day, whence its name, the day-fly (*Ephemerus,* which is our 'mayfly')." Cicero (*Tuscul.* 1. 39, 94) refers briefly to this account, without mentioning the four legs and wings.

[163] The Greek word "Ephemerus" means "lasting for a day."

[164] "vitae usus."

[165] "conditrix"—evidently "Mother Nature."

[166] "Promuscide"; "promuscis" is a "corrupt form for proboscis" (*L&S*).

[167] "meditari."

[168] "invisus"—can also mean "invisible."

[169] The passage from here to [E] on 657 (1560) first appears in 1554.

[170] "Saccensis"; not identified.

[171] "Concava litoreo si demas bracchia cancro,
Cetera supponas terrae, de parte sepulta

Nature evidently did not overlook the kind of ants, as indicated by this change, by their lengthy life, by their diverse kinds, and by the republic[172] they maintain. [E] Just as the bees guard their kingdom, the ants look after the organization of their community.[173] Some of them increase a good deal in hot regions, so much so that Rhazes reports that in Sufis, the celebrated town of the Persian district, an ant was fed at the public expense, in fact at the Avian forum, which consumed a pound of meat daily.[174] In the West Indian Isthmus, Sur and Nort, other ants construct little cottages as bees do, so hard that they can barely be split by axes, and in this way destroy trees.

Among the kinds of wingless cockroach, those of grain are notable; if they get nourishment among the bran, they burst out in marvellous abundance—over an interval of a few days, from ten to three hundred of them. They grow for the feeding of black-headed tits[175] and nightingales, and no food is more healthy for them in winter, when most barbers are concerned about this;[176] they purge and heat up animals that possess little fuel for life.[177] The kinds of some cockroaches alter as bees do, by a great miracle of nature, nature which does not seem to have overlooked them in so manifold a metamorphosis. And among the rest there is a kind of caterpillar that during conversion to aurelias[178] mimics the &658 form of an infant enclosed in baby clothes, with a human face virtually accompanied by a turban[179] and horns; others are of a golden or silvery colour, so that it would be no wonder if there were something anomalous in them which escapes us. Or maybe this would be a chance event; but in a whole species it could not be a

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Scorpius exibit caudaque minabitur unca."
(Ovid, *Metamorphoses*, 15. 369–371)
Only 1560 contains this quotation.

172 "Politia"—the Greek word for "republic" transcribed into Latin.

173 "popularem statum."

174 "In India near the Equator there is a land in which . . . the ants are like dogs, and faster than any of God's creatures; their business is extracting the golden sand from their mines . . . and someone reported to me who had seen an ant of Baldacus in the Avian, which ate a pount of Baldacine flesh daily, in the time of King Almuzedie, and the ants close up the sites of their passages before showers and rain occur" (Rhazes, *De facultatibus partium animalium* [Basel: Henric. Petri, 1544], I. cap. 34 [583]). He does not mention Sufis here, nor "at the public expense," and goes on to mention that an ointment made from these ants is helpful in erectile dysfunction.

175 "Melanocephalos"; on the identity of any bird of this or similar name, see discussion in D'Arcy W. Thompson, *Greek Birds,* 195–96, who points to ambiguity in modern Italian equivalents. Pliny (*Nat. Hist.* 10. 44) uses the word "melancoryphi" which in Greek has virtually the same meaning.

176 "tonsoribus plerisque hanc curam habentibus"—sense obscure.

177 The rest of this paragraph first appears in 1554.

178 See n. 147 above.

179 "mitra."

chance event. There is a species of them that are generated from eggs by unbroken succession, or only from decay.

The smallest of this kind are among those known to Aristotle: the acaris,[180] which arises in wax; nowadays the West Indies produces another new kind, Garapatem, finer than ground salt—and also a frightful pest from the flea kind, Niguam. This animal is much smaller than a flea, and while latching on to a person causes such mangling while invisible and impossible to grasp, that in some cases they destroy the victim's feet and in others the hands. Help can be obtained if the place is anointed with olive oil and is scraped with a razor.

The[181] harm these pests do is not to be completely disregarded, since the smaller these animals are, the more plentiful and disgusting[182] they are. Hence in the case of the Myuscian[183] peoples in Achaea of old, since their homes were by the sea, and their region was cleansed by its busy tide, the inflowing river Maeander gathered sand together and enclosed a marsh. Such a supply of mosquitoes emerged from it that they were forced to abandon their town. For as we said, such creatures affect everything through their abundance and their disgusting and foul character. But in addition to the rest, mosquitoes add a hostile buzz, and make their attack aggressively, so much so that during the day it is &659 uncomfortable to live near marshes and bogs (mosquitoes love them), and during the night very uncomfortable indeed.

So the ancients have written down many expedients against these misfortunes. But to start with, one general approach[184] should be based on touch, one on smell, and the third on taste. From sight and hearing there can be no general approach, since these senses are very feeble in these creatures. In fact, as has been said, all their senses are feeble, since their generation takes little time, and also their body is tiny. However, sight and hearing, being (as we will explain later) less essential for life, are overall weak in them, so that highly sagacious animals (particularly the social ones—bees and ants—as just mentioned) completely lack one of these; bees lack hearing, since they fly and [516]need sight, and ants lack sight, because an earth-bound animal has not such need of sight—their horns are a help, serving as walking-sticks to feel for the way, as is the case with snails. Ants lack eyes because of their dry temperament, and snails because they are so small; being blind, they have been provided with horns instead of a walking-stick. An animal without sight cannot fly sufficiently cautiously to avoid hitting something and falling. Nature has removed hearing from bees, since they are

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[180] ἄκαρι, a kind of mite arising in wax, as stated here; see Aristotle, *Historia Animalium*, 5. 32. 3.

[181] The material to [F] on 663 (1560) appears first in 1554.

[182] "taediosa."

[183] "Myuscii"; possibly "Mycenean," but there is confusion here because the river Maeander is in Asia Minor and not in Achaea.

[184] "ratio."

small and need their eyes, in case a pair of senses packed in such a small head were useless through imperfection. So ants were blind, and bees deservedly deaf; yet perhaps both of them keep some perception[185] of the missing sense.

But the other three senses, &660 imperfect though they may be, flourish the more because needed for life. These are, as I said, taste, smell, and touch. A scheme related to them has been discovered to repel these animals. Through touch they avoid metals and stones, on account of their coldness; being bloodless, they are cold, and are enormously damaged by cold, through lack of heat. Bedbugs are killed by smearing on lime, since they live in crevices in room walls—so it is a good plan to move beds away from room walls. And they live in books, so stuffed with blood that they are certainly like that by nature and not by drinking it. Hence their generation depends very greatly on human spirit.[186]

They can be repelled by smell, since they all avoid the odour of burnt creatures of their own kind. Thus locusts, taught by nature, avoid the stench of locusts, and ants that of ants, and hornets that of hornets. And they avoid any excessively dry odour, and so keep away from cedar resin (even if not burnt), and from hartshorn while being burnt; as these animals are dry, as I said, they are powerfully upset by dry things.

Through taste they avoid bitter things, such as wormwood and abrotonum.[187] Hence they avoid such things when sprinkled in clothing, and leaves of citrium[188] and of nard, and sabine cedar resin—these for a twofold reason: the first because they are bitter, and the remainder because they disseminate a powerful dry odour. On the same basis, the smell of vinegar drives away mosquitoes and the like; it is pungent. But it does not drive off flies, because (as the saying has it) the mosquito enjoys sweet matter more, being generated in water and in damper places than the fly. This is why people say that a sponge full of pungent vinegar &661 hung up in the middle of a bedchamber prevents the entry of mosquitoes into that room. In places where they are plentiful, people shut the chamber windows before illumination is brought in; like most of its sort, this animal makes eagerly for the shine of a light, so much so that there is a kind of moth that keeps approaching a light so often and so close that in the end its wings are burnt up by fire and it falls down dead. In common speech this kind is called "farfalla";[189] if it has no Latin name, it can be called "erophon"[190] in Greek. Things that exclude them are (as I said) all pungent and bitter, yet for an

[185] "imaginem."

[186] "spiritu," a word also covering "breath." See n. 47 above. The three previous sentences first appeared in 1560.

[187] An aromatic plant mentioned by Horace, Celsus, Pliny etc., and often linked with wormwood.

[188] A kind of gourd (*L&S*).

[189] Italian for "butterfly" or "moth."

[190] Not traced as a Greek word.

odd reason stavesacre,[191] what you might call "woodland grape," excludes them, so much that when rubbed on with oil, and if you tie round your head a thread steeped in it, all the lice make off or die. Mosquitoes are excluded by flowering hemp attached to the bedchamber. People suppose, too, that they do not enter when horsehair is hung up in front of the chamber—and this looks more like a fable than a trick. Among the earlier kind is the wild cucumber, black hellebore, the greater dracontium,[192] and the radish—people say that those who are anointed with its juice are immune to snakebite. Further, the smell of burnt skin, which also generally restores hysterical women, puts snakes to flight. There is a tale that a man who had consumed a viper in his sleep was delivered by the smoke of skin, the viper escaping from the smoke which the sick man was taking in by mouth. Certainly, all snakes are put to flight by fire, and not just snakes, but most of the wild animals. And what puts snakes to flight also kills and puts to flight all the insects. However, many kinds of insect are fond of a little fire and light—for instance, flies, mosquitoes, moths; and &662 crabs and the grey mullet, to their destruction.[193] All these, however, are afraid of a large fire. Fire kills them, too, and destroys their eggs and the filth by which their kind (as I said) is recreated.[194] Again, everything that habitually lurks in wetness[195] perishes very quickly in the sun. I recently wished (in July, in fact) to put scorpions into oil, a preparation I regularly make against fevers; I put them in the sun, and at once they started to scuttle out of the bran. There were about ten of them. I used to think that they became more lively through the heat itself, but found them all killed in a moment. It could be thought verging on a miracle if the same did not happen in moles.

Some things do repelling through a special property, as the plane tree is said to do to bats; people state that this animal does not approach it. It is an invaluable discovery to have mixed the watery residue from olives[196] with lime for anointing rag shops, to stop spiders or moths infesting the rags—and it stops damp.[197] And perhaps it is through some special property that the watery residue from olives fends off all insects, whether it does it by odour, or whether the moisture prevents their being generated; they are generated from moisture, or from all these things. We will develop some points too about these later on, especially an unwelcome animal against bedbugs (and with a particularly foul odour),[198] and against ants.

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[191] "staphisagria," the plant *Delphinium staphisagria* (*OLD*).

[192] A large species of arum lily.

[193] This is probably a reference to fishing with lamps at night.

[194] The rest of the paragraph appeared first in 1560.

[195] Reading "hudo" as equivalent to "humido"; see n. in Book II at 226 (1560).

[196] "amurca."

[197] "udum," properly an adjective, and see n. 195 above..

[198] In Book XVIII, 1142 (1560) Cardano mentions that a wooden ball smeared with fat attracts bedbugs, but specifies no animal.

Now let this suffice as an account of these issues. Before our time, the ancients failed to identify the issue[199] and were so blind that Pliny denies that locusts have eyes, as if he had never seen locusts;[200] their eyes are obvious and very large, but of blunted sight, as we said. Even if &663 we had never seen locusts ourselves, we would have had the courage to pronounce confidently that they had eyes, because it would be impossible for an animal endowed with flight to be blind—furthermore, if you put out the eyes of a flying animal, it stops flying, bearing in mind the risk.[201] This and other questions can be grasped by a demonstration.

[F] It seems appropriate for animals generated from decay, being insects, that their severed components[202] should grow again[203]—like the tails of snakes and lizards, the claws of crabs, the eyes of swallows for sure, and (as many people think) of snakes too. The reason is that they are imperfect; hence eyes do not regrow in swallows, but do in swallow chicks; and very often in fetuses too, damaged components are restored while they are in the womb. Physicians would say this is because they are moister.[204] It might perhaps be said that both reasons are valid.

Among the kind of insects there will be, then, tortoises and crocodiles and chameleons and all the quadrupeds that are generated [517]from eggs; they are not generated through some necessity from eggs, as fish or birds are, as we will show later on, but because of the imperfection of their nature. So severed components from such creatures as these are restored; the nature of an egg is undistinguished, and barely a trace of semen can be made out in these.

Further, these three have a remarkable nature. We should then discuss the crocodile first. It is an animal very like a lizard, but has very sharp teeth, protruding externally, big ones, and strong claws, an impenetrable skin like bark, and a very powerful tail. Firstly, it is &664 alone in moving the upper jaw but keeping the lower one immobile.[205] A second marvel: it goes on growing as long as it lives. It lives up to sixty years, and has that number of teeth, and in the same number of days is hatched from the egg, and lays eggs to the same number, so that it seems to conform greatly to this number. From an egg very like a goose's

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199 "ratio."

200 In fact Pliny (*Nat. Hist.* 11. 140; Loeb 3: 521) reports one Nigidius as saying that locusts and cicadas have no eyes.

201 It is not clear that Cardano is aware of the flying capability of bats, which use acoustic information. Aristotle does not mention this, unless vaguely in a suspect portion of *Metaphysics* (2. 1. 3; 993b9–12 Loeb 1: 85), which contains the cryptic remark, "just as it is with bats' eyes in respect of daylight." Nor does Pliny (*Nat. Hist.*)

202 "membra."

203 Scaliger (*Exercitatio* 195 [632–33]) comments that Cardano loses track here of which creatures are generated from decay and which not.

204 This book ends here in the 1550 edition; 1554 and 1560 continue.

205 See Herodotus, *Hist.* 2. 68.

egg it sometimes grows to a length of eighteen cubits.[206] This animal has a fifth notable feature, in that although it is terrestrial, it spends its life as a fish; it is almost always lurking in water, especially in the river Nile. There it possesses the marvellous feature that above the town of Cairo it rages and kills people, but is mild below there. They are alleged to have grown much more ferocious than previously, over the seven hundred years in which Mohammed's devotees have possessed that region; and the reason for this is that in the foundations of a temple these devotees found a lead statue of a crocodile with Egyptian lettering, and when it was melted down, the crocodiles were enraged subsequently. The priests used to tame them in a remarkable fashion, although no animal that lives in water genuinely gets tame, especially not this extremely cruel one. I would like to quote the actual words from Strabo, confirmed on this point by Aristotle too and those later. Here they are: "In the prefecture of Arsinoë a crocodile is worshipped in an extraordinary way, and is sacred to them; it is fed separately in a lake, and is gentle to the priests, and is called Suchus. And so a host, a man very respected among the rest, who showed us the rites, &665 came to the lake and brought a small cake and roast flesh, and a vessel of honey with wine[207] from supper. We found the beast on the bank of the lake; one of the priests opened its mouth and another put in the delicacies, then the flesh and the honey with wine. The beast leapt into the lake and crossed to the far side."[208] Yet this so strong and huge beast is in fear of the Tentyritae (they too are Egyptians). Strabo actually says soon afterwards, that when crocodiles were brought to Rome to be on view, the Tentyritae were following them. A fishpool was made for the beasts, with a gap in one of the sides so that they could go out from the water into the sun. The Tentyritae were there, and used sometimes to lead them out into the sun with a net, to be seen by the spectators, and sometimes they entered the water and dragged them back into the pool.[209] It is believed that they calm the crocodiles by giving them a medicament; medicaments kill little beasts, but usually calm large ones first. Thus in this animal so many varied features worth astonishment are available to be seen. It has very sharp sight when out of water, and since it cannot easily turn itself round, if anyone in flight runs slantwise, it does not follow— if it did, escape would be very difficult. Many dead ones are brought to us, and are distinguished from the larger lizards that originate in India, and whose dung smells very well, or they are distinguished by their body, with the lower jaw immobile, and the teeth.

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[206] About 11 metres. But the largest (Indo-Pacific) crocodiles now hardly exceed 7 metres.

[207] "mulsum."

[208] Strabo, *Geography*, 17. 38; Loeb 8: 107.

[209] Strabo (*Geography*, 17. 44; Loeb 8: 117) describes this display as occurring at Rome. The town of Tentyra was in Egypt near Abydos.

The chamaeleon is less common, and much smaller, but is included in this book through a much greater marvel. So I will relate first what Aristotle wrote about it, who, as we can deduce &666 readily from his words, knew it and carefully handled it, and also dissected it. We will end by adding what we have learned from others. These are Aristotle's words:[210] "In the shape of its whole body, the chamaeleon clearly resembles a lizard: ribs drawn downward are linked to the abdomen, as in fish, and the spine is prominent as in fish. Muzzle closely resembling that of a pig-faced baboon monkey.[211] Tail very long, ending in a thin portion, and curled on itself in numerous long rings, like a strap.[212] It is at a higher level above the ground than a lizard, but has bent legs as lizards do. The individual feet are divided into two, and the parts have a relation to each other such as the thumb has to the rest of the hand facing it. But the remaining parts too are cloven to a small extent into digits: the front ones with a triple internal split and a double external one, the back ones with a double internal one and a triple external one. Little hooked claws, the whole body rough, like a crocodile. The eyes sunk inside in a hollow recess, very large, rounded, covered with a skin like the rest of the body, and with a very small middle part uncovered through which they can see. This opening for seeing is not covered anywhere with skin. It is not by movement of the pupil but by rotation of the whole eye and its conversion into a sphere[213] that it looks in any direction it wishes. When puffed out,[214] it changes its colour: dark, not unlike a crocodile, and pale like lizards, and marked with dark blotches like the leopard. The colour alters over the whole body: both the tail and the eyes are of a colour with the body. Movement slow, like a tortoise, and when it dies it goes pale, and after death does not change colour further. It has the gullet and trachea[215] &667 in the same position as a lizard's. It possesses flesh nowhere, except on the head and jaws, and a very little of the tail at the back.[216] No blood, except in the heart and eyes, and in a spot above the heart and in the veins leading to there. Indeed, there is no large supply of blood in them, but only a tiny amount. A brain located above, close to the eyes, and almost touching them; the eye is surrounded by a thin bright circle like a brass ring, which is visible when the outer skin of the eye is pulled off. The membranes extending throughout the body are numerous and strong, and much more robust than in the other animals. Even though wholly dissected, it goes on breathing

210 Aristotle, *Historia animalium*, 2. 11; Loeb 1: 109–13.

211 "Simia porcaria."

212 "lorum."

213 "in orbem mutatione"— meaning unclear (turning round about?).

214 "inflatus."

215 "Arteria"; the "rough artery" is the traditional name for the trachea, and indeed "trachea" is the Greek word for "rough."

216 The original Aristotle (Loeb 1: 111) reads here: "It has no flesh anywhere except some tiny portions on the head and jaws and the root of the tail."

for a long time, a tiny motion being still retained around the base of the heart. And when it contracts all the parts of its body, it can greatly contract and draw together its ribs. It does not have a conspicuous spleen. It goes down into caves and lies low, like lizards." Aristotle, I say, elsewhere so concise, is so lengthy here, [518]attracted by the great marvel of it. But those who in our time have seen them add the following: its body is nearly green, with a certain glitter, and with patches marked with matt white and blue. However, under the abdomen the green colour is more dilute, and wherever the patches are, they virtually represent the shape of keys, since they appear to protrude and are a little rounded. Its gaze is quite lively, and cheerful, because its eyes are green, and with a mix of shiny white and tawny they hold a lot of light, and so it looks happier. But when either matt white or blue is placed on top of the green colour, its normal native &668 colour flourishes and blossoms, the other two not altering. Each is preserved in its own portions. But when the green colour is placed over the dark colour, it is remarkably dimmed and dulled, and the patches alter. The same thing happens to it without colours: when it is harassed or forcibly held, it changes the patches into dark, and the green colour is obscured. Likewise, when cheerful and lively, it redoubles and fires up[217] its natural colours, so much so that it is obvious that the animal's colour change occurs because of its mental experiences.[218] When turned towards the Sun, it receives its rays with mouth agape, and gulps up air; gradually its neck starts swelling, then the rest of it, till with air getting down into the depths of its stomach, even that part swells up. It is born in Socotra, an island of East India.[219] Moreover, in the words written above, Aristotle affirms that it consumes air, but did not say that it uses no other food. So either this is not true, or he did not know it. There are people who steadily assert that it eats food, not air, because it excretes.[220]

Perhaps someone will say: "How far is it right to transfer Aristotle's writings into this book in so many words?" But our purpose is to present the causes of highly obscure things, so that the discussion would serve no purpose unless its reliability were created by the testimony of such a distinguished man, and reinforced. The points needing demonstration, then, are how this animal changes its colour, and how it can live without food.

But you will say: "It does not live without food." I do not dispute this—but it is generally established that many animals, such as the bear, toads, and snakes, live a long time without food. Again, &669 cicadas are observed to live like this. So if I come to have explained in how many ways an animal can live without food, I think I will have achieved something. But first, another problem needs solution. This is it: why does a chameleon change its colours? Everyone knows

[217] "ingeminat ac accendit."
[218] "animi affectus."
[219] Off the Gulf of Aden, and north east of Somalia.
[220] "egerat," from "egero," a Late Latin word meaning "discharge."

that enraged people redden, and virtually turn black, but they grow pale when frightened, so pale that some of them look as though dead. In embarrassment, all the blood is agitated,[221] the heat comes and goes, and especially in boys, as your Mantuan poet,[222] may I remind you, taught us beautifully, saying: "But if the moon has made a virginal blush tint its face. . ."[223] And so where the skin is thin, and the blood is readily moved to well up, there has to be a different colour, and such a change is seen in the first age of human beings, and more often when the humour[224] has turned out thinner. So where the skin is thin and translucent, and the humour thin, and if the reactions[225] are powerful at that point and there is no hair there, there has to be a change of colour. All these features are present in the chameleon: translucent thin skin, thin humour, no hair, and it is subject to strong reactions such as fear and grief. It is in fact an animal with quite scanty blood, and thus timid by nature, and for that reason passes readily from joy to grief. And so it is no wonder that the chameleon is altered by its reactions.

But someone will say: it is altered not just by its reactions, but also by the presence of a colour, and to a colour like the existing colour. But as I have said, it does not alter into any colour, &670 but only on the plan described. So let us imagine that a matt white colour is present; while it[226] is seeing it, the matt white part is fired up,[227] and thus redoubles its colour. In human beings, we do see that when they have mentally perceived the woman they love, their penis is erected, but all the other parts are entirely unaltered. If there is a frightening thing, the heart flutters at once, not the foot or the penis. And so the same thing occurs in the chameleon; the parts of similar colour draw watery clear humour towards themselves, and thus all the colours are brightened. Pick an example from the goldsmiths: they put leaves of silver under carbuncles, emeralds and sapphires, yet they are all lit up, and the gems radiate their colour more brightly.[228] To all of these are added the diverse appearances of light which the skin's sheen contributes, as on a pigeon's neck: that neck takes up brightness in a varying fashion through a moderate alteration. A major contributor to this is the supply of air that engorges it; in the throat of Indian peacocks (they change the colours of their

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221 "concutitur."

222 Vergil, born near Mantua; and "your poet," because the dedication of the 1554 edition is to Ferrando (or Ferrante) Gonzaga and states that many of his ancestors were lords of Mantua. This Dedication appears before Book I of the current translation.

223 Vergil, *Georgics*, 1. 430. The poet is depicting an appearance of the Moon's face that presages wind.

224 Blood.

225 "affectus."

226 The chameleon.

227 "accenditur."

228 The remainder of this paragraph appeared first in 1560.

hood[229] into matt white, red and scarlet, with other patches also glinting among them) so much air is held that you might say it is an inflated drum. In this way these two animals[230] are engorged with breath, and are tormented by great reactions, and visibly alter colour. Thus the more potent cause, in which they agree, is the confined breath, and a distension arising from it.

But another reason needs enquiry to explain why it lives without food; as I have said, on Aristotle's authority cicadas too live without food. The evidence is that they have no mouth, and when dissected have &671 nothing in their stomach. And this is the more remarkable, because most of them chirp all day, and produce eggs, and grow, and have a hard skin, and copulate—all work for food to do. In the past, before they shed their chrysalis skin,[231] they used to be eaten, being sweet, and their eggs too, on Aristotle's authority; the cicada in fact is initially a worm born from an egg, then a chrysalis,[232] finally, with its skin shed, a cicada—and then it is harder. The eggs are shiny white, and very sweet-tasting. So it is clear that they are being fed, and without food or drink. For they thrive in dry times and hot regions, without rain, and are fond of the olive tree because of the scanty shade. So they are nourished by the dew of heaven; from dew manna is made, by which the Hebrew people were nourished in the desert. And it being clear that even nowadays people are nourished by manna, how much more could it be food for such a tiny animal? So they are nourished by dew, and by the air itself as well; air always contains some corpulent moistness.[233] The evidence is the stones belonging to the kind of flints or marbles, which are always damp, and the [519]rays of the Sun.[234] So since the heat has been very rarefied, this humour gathers—at other times it is dispersed,and when gathered it is concocted, being fatty. The evidence is the sweetness of manna. Living with a large food intake suits snakes too (as already mentioned) and toads and bears and hazelnut mice[235] and all these animals that lie low in winter and have nothing stored up. So an animal can always survive without food and drink on a double basis: either because it retains the remains of its original &672 voracity, or because it is nourished by the

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229 "cuculla."

230 Chameleon and peacock.

231 "corticem tettigometram."

232 Aristotle (*Hist. animal.* 5. 19; 551a16–19; Loeb 2: 175) writes, "at first the creatures are smaller than a grain of millet, then in three days they are small caterpillars; after that, having grown still more, they remain stationary, and change their shape; chrysalis is the name then applied to them." But this passage is about *butterflies*, and when Aristotle discusses the generation of cicadas (*Hist. animal.* 5. 30; 556b6–15; Loeb 2: 207), the account is quite different, and he does not use the word "chrysalis" at all.

233 "corpulentum."

234 The logic is not obvious.

235 "muribus avellaneis"; perhaps dormice ("glires") are meant, but these do of course get very fat for the winter.

sort of air we ourselves use. And this latter source of nourishment is continuous, but the former one occurs at the time, as is usually said. Sometimes these causes are combined, so that there are some men who have lived a long time without food; an account of these will be for presentation at the proper point.

Consequently I am astonished at people who have tried so diligently to overthrow what has been said about the chameleon; for even if it did not live without food, it could still survive, since cicadas live like that. But is it not alive? Certainly, as the lawyers say, this is a question of fact, which does not debate whether it *can* happen, but whether it does happen like this—and maybe we can trust the account over this.

So with these points made good, what remains is to display the marvels of the tortoise: firstly, this animal lives a whole day with its head cut off, and no other can live so long like that. As Aristotle too affirms, it can live a long time with its heart cut out, although it possesses blood. There are three kinds of tortoises: the terrestrial, living in woods; the aquatic, living in the sea; and the marsh tortoise, which is born in marshes. The marine ones[236] have wide cartilages instead of legs—nature has constructed limbs so well suited to each use. The marine ones and the others grow to a huge size in hot regions, such as Africa; moist fattiness (as already made clear) is widespread in hot regions; hence tortoises, fish, snakes, elephants, all these grow huge. The West Indian ocean produces the largest, so that a team of &673 six men could hardly carry one. I saw one of these at Padua which had died there, but it was only as big as a shield. Some people say they have seen a shell weighing a hundred and twenty-three pounds—just think how big the whole creature must have been. It is known that shells are so big that the Indians use the smaller ones as shields, and the bigger ones to roof their homes.

Among the Romans of the past, the shells of Indian tortoises were in demand; they used to be cut up into pieces and separated into plaques with various uses, when bands[237] of ivory or gold were added—a technique that could still be restored to use. It is claimed that the flesh of African tortoises, taken for seven unbroken days with bread, cured by a great miracle the elephantiasis of a man who had suffered from that disease for not more than seven years. The reason for this is the dryness of these sorts of flesh, along with the strength and temperament of thin and suitably fatty moistness. Eggwhites of our own tortoises, when heated on fire, do not coagulate, hence they do not need to eat much earthiness; things that are earthy, such as bricks or gypsum, clearly do coagulate. Their life is reckoned to be long, but I cannot state anything certain about this. What is utterly true is that this animal has a very large liver, and has the only bladder among the egg-laying animals. This will make anyone uncertain why so many miracles happen in these imperfect animals, and so few in plants and in the perfect animals. The reason is twofold: one is, that in the latter deficiencies occur

236 i.e. the aquatic kind—turtles.

237 "limbi."

instead of miracles; there are numerous monstrosities among them, as has been stated; the remaining reason is that in their juice &674 these animals do not correspond to the perfect ones—all the perfect ones have a single juice, which is blood; but these individuals have their own juice, and accordingly each has its own special and peculiar powers, which seem extraordinary when they do not correspond to those of the whole kind—rarity always begets astonishment, frequency makes a thing look natural. Nature appears to have been so fond of those offspring of its own that it wished the most pleasing of the fish kind (such as the burbot[238] already mentioned, and eels) to come into being without seed and without a parent. Among the blood-containing animals this is the only one generated from decay, and it is sexless and has not even a start to its generation. It lives a long time without water, even up to five or six days, since it needs little cooling, and enjoys rarefied water. As already mentioned, air always contains some portion of more rarefied water. It is believed to be generated from burbots, which are called the bowels of the earth—and surely there is a great resemblance between them, and the obvious surmise is that for eels no other origin is found, nor any other end for burbots. We have, however, often eaten two-pound burbots at Lyons, and bigger ones—but not the kind of our own small Italian ones—ours are rounder, and do not reach the same size, and live not in water but in mud, and are darker. The taste of the French ones is less attractive than that of eels. A characteristic common to both is complete absence of bones; instead of a spine they have a rounded fibrous[239] membrane like a rope.

&675 Being so rare in Italy, many people regard the big burbots as better than eels. The river Rhone[240] and the Loire[241] offer many of them in spring. Nature has sported in this way in every kind, and has made the topmost match the lowest, and the lowest the topmost; in such a lowly kind of dead things, the comparison with resurrection is not missed. Indeed, it is thought that flies and anchovies[242] return to life. This is remarkable in the case of the flies, but I am not much concerned about the anchovies: they are so readily generated from rotting dung and the filth of many other fish that it is no wonder that from their rotting selves other intact ones are generated.

There are many remarkable features in these, but the age to come will show other and greater ones. Let it be enough for us that we have reached the main points and the whole enquiry in outline,[243] linking the causes, so that one can

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[238] "mustela"; see n. 142 above.

[239] "nerveam."

[240] "Rhodanus," of southern France.

[241] "Ligeris," of central France.

[242] "apua"; Pliny (*Nat. Hist.* 9. 160; Loeb 3: 273) simply says that anchovies get warmed by sea foam when the rain gets into it, and also (*Nat. Hist.* 31. 95) that they are "bred out of rain" ("is pisciculus e pluvia nascatur").

[243] "per capita."

move on from these to the remainder which are passed over here; if I get to wanting to cover them in detail, they will turn out innumerable. And one can know what is true, what is absurd, what is possible, what is not, and can separate fable from truth, which is the intention of the present plan.

[520]The only question that will perhaps be fit to excite the astonishment of many people, is why these creatures of almost no usefulness have been given by nature numerous aids for self-protection, but others have been given almost none. The chameleon, for instance, the sound of its name[244] suggesting a lowly or earthly lion, has no teeth, no gallop, no strength, no claws—the crocodile has the keen gaze of such a fearful beast, very sharp and strong claws, and &676 murderous teeth, and such speed that it chases even the less well-endowed dogs. Hence the origin of the adage, "Like a dog drinking and sucking at the Nile."[245] Skin impenetrable; a tail so robust that it overturns small ships; it trips up all the legs of horses at a single blow, so that it seems that nothing further could be devised for its security. A final addition, the largest: it lives in both elements without distinction, a privilege granted so freely to no other animal. Thus if some violence threatens it on the land, it takes to safety in the water; and if threatened on the water by a more powerful enemy, it retreats to safety on land. Maybe indeed this animal should be listed among the perfect ones; the elephant ranks among the quadrupeds, the eagle (or anything that may be better than the eagle) among the birds, the whale among the fishes, the human being among all of the animals; the "regulus"[246] (unless it is fabulous) among the snakes—in the same way, the crocodile is prominent among the amphibia.

In the leader[247] of each kind, nature has made a special effort. The crocodile is not generated from an egg because of its humble origin, like the caterpillars and spiders and lizards, but because of the convenience, as in the case of the birds. We will deal with these points in the next book, and so let us proceed to the remaining item in this section.[248]

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[244] And its Greek etymology.

[245] This adage is contained in the *Adages* of Erasmus (I. 9. 80; *Adages*, ed. Mynors, Collected Works of Erasmus 32, 223; on Erasmus see n. in Book VIII at 534 (1560), where his editor remarks that it refers to people who take a mere sample: "This adage took its rise from a witty remark which is recorded by Macrobius in book 2 of the *Saturnalia*, and goes as follows: after his rout at Modena, people were asking what Antony was up to, and some friend of his replied, 'He's like a dog in Egypt, drinking on the run.' For in those parts it is well known that dogs have to keep running while they drink, in terror of being seized by a crocodile."

[246] Or basilisk, a monster; see nn. 45, 46 and 47 above.

[247] "coryphaeus."

[248] "reliquum divisionis membrum."

[520] &677 Book X
On Perfect Animals

Even though Aristotle was not aware of these, some of the perfect animals live in the air alone, and have no legs—for instance, the Manucodiata.[1] Others live in air and on the ground, as the eagle and most of the other birds do; others are terrestrial, but resemble birds, like the ostrich. Others share water and land, like the beaver. Others are swimming birds, like swans. Others are flying fish, like "marine swallows."[2] Others are purely terrestrial, like dogs; others live underground, like the mole;[3] others live in water alone, like the dolphin.

It is not in our plan to deal with all distinctions, but only these nine kinds, and the more notable species within them.[4] There is another division, by behaviour,[5] and another by manner of life, and another by method of generation. By behaviour, since some are savage, others tame, some domesticated, others wild. By manner of life: some live on meat, others on plants and things like that. And by method of generation: some are generated from eggs, some from decay, some

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[1] This is the Bird of Paradise from the East Indies, and dead specimens of it reached Europe in the 16th century, without feet, which started a belief that these birds never touched down on the ground—a belief jestingly resurrected by Linnaeus in 1758 when naming the species "Apoda," lacking feet. Ray noted in 1692 Aristotle's belief that no winged flying creature lacked feet, and did not believe the tale; he (*Wisdom of God* [1692], part I, 147) wrote: "As for the story of the *Manucodiata*, or *Bird of Paradise*, which in the former age was generally received and accepted for true, even by the Learned, it is now discovered to be a Fable, and rejected and exploded by all Men: Those Birds being well known to have Legs and Feet, as well as others, and those not short, small, nor feeble ones . . ." Also see n. 454. The martlet, a legendary bird appearing in heraldry, had tufts of feathers instead of legs; on this see in *Wikipedia*.

[2] "volucer hirundo": Pliny, *Nat. Hist.* 9. 82.

[3] Scaliger (*Exercitatio* 197 [638]) disagrees about the mole being a perfect animal; he thinks it arises mainly from decay, and has a poor power of sensation. He has many other modifications to propose here.

[4] Material from here to [A] on 682 (1560) is new in 1554.

[5] "mores."

from animals. From eggs in four ways: the birds, the fish, the snakes, and some low-grade insects, such as silkworms, cicadas, caterpillars. So to start with, three points need explanation. One is why all birds are generated from eggs, although they are perfect animals. Secondly, why fishes are. Thirdly, why imperfect creatures cannot generate an animal.[6]

&678 The first point, then, appears to have happened with good reason:[7] it was necessary to generate either a few chicks, or many birds. If little birds had generated few chicks, their kind would quickly have perished, because little birds are consumed by large ones, and caught in nets, and seized by snakes before they can fly. Meanwhile their eggs are stolen, they die of hunger and cold and a thousand other perils. So little birds—indeed, all little animals—produce numerous chicks or young.[8] Big birds generate big chicks; this is why, if big birds carried large fetuses in their belly, they would weary with the prolonged heavy burden, or the chick would have to be soon delivered, and thus birds would necessarily be not perfect, but imperfect, animals. Again, in the case of little ones, if the mother were carrying all the fetuses in her belly together, she would be overloaded by the excessive weight; if she carried one after another, she[9] would be involved all year in feeding and bearing chicks. Not only so, but she would fall victim to difficult times of the year, and be exposed to wild beasts and predatory birds. So it was impossible for birds to be procreated out of birds, as beasts are out of beasts. But while chicks emerge from the egg, a fourfold advantage ensues: the male is not compelled to copulate all year, copulation being extremely injurious to the bird kind, because of dryness—hence the sparrow does not survive more than two years.[10] Again, the mother is quickly relieved of the weight; an egg proceeds from being small to complete size in a single day, or in two days as the limit. This is obvious to those who dissect hens, which &679 generally produce an egg in a single day—you will see one large egg, another medium sized, evidently because it was going to be laid the day after to-morrow, and the many eggs left are very like grains of sorghum[11] or millet.[12] Eggs once laid and at first incubated for a long time by the bird without disadvantage can generate a perfect animal; and a number are incubated at the same time, so that what could hardly be accomplished in four or six months by carrying chicks in a womb is completed in eggs

[6] On the inability of imperfect creatures to generate, in Book IX Cardano remarked, "But Aristotle denies that such animals generate, and is right"; and further explanation follows; see n. to Book IX at 629 foot (1560).

[7] "ratione magna."

[8] "catulos."

[9] Although the text reads "essent," I have translated as though it read "esset."

[10] Scaliger (*Exercitatio* 269 [816]) mentions having watched one in a cave fly more than ten times within a few moments to a female to enter her.

[11] A grass related to sugar cane and grown in the tropics.

[12] A food grain.

in a single month. So it is clear why birds do not bear chicks, but eggs. But some do bear an animal, as the bat does; it, the only animal among the winged creatures, bears an animal, [521]not an egg,[13] since it does not fly much—it lies low all winter, and only flies during the rest of the year, and only at twilight. It has teeth, not a beak, breasts with milk to nourish its offspring, and wings constructed from a membrane, not from feathers. But this is a feature shared with the flying foxes. These are not birds, though they fly; creatures that actually are birds are clad in plumage, have a beak rather than teeth, have no bladder, nor breasts and milk, and lay an egg. The eggs of birds are bicoloured, but those of fish only of one colour. Fish produce incompletely developed[14] eggs, which complete their development externally. The reason for the incomplete development of their eggs and their uniform colour and their normal generation from eggs is the profusion of them; a fish cannot produce as many animals as it does eggs. Again, a fish generates eggs because if the animal were generated in a womb, it would be generated from blood, and the fish would be sanguineous and hot, making it need a lung and air—so it would not be a fish. &680 Consequently the seal,[15] an animal that does not generate an egg, does also breathe, and has a hairy coat, on account of its warmth. In such a cold element it would be hard to conserve enough heat from which a perfect animal could be generated.

The reason for the profusion of fishes is the easy handling of the element; water is the principle of generation. Another reason is that little fishes are the food of the larger ones; there are not in fact as many plants, cereals, and fruits there for the fishes to eat as there are on land. "Food" and "animal" are nearly the same; nourishment comes mostly from animals (I refer to the larger ones). Again, fishes are of little sensory ability, and are animals lacking the ability to learn,[16] so it was inevitable that a fetus would be neglected by its parent, and consequently the majority of them would perish, so there was need for much generating;[17] animals love and protect their fetus in proportion to the extent of their ability to sense and their prudence. Indeed, protection comes into being on account of love, and love originates from ability to learn.

Consequently the very imperfect animals only conduct the care of the fetus as long as they hold it in the womb. Those that are more perfect do so until they have brought it out from the egg into the daylight—they guard the eggs, they ignore the animal once fledged. Those that are perfect guard their offspring till

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13 The rest of the sentence appears first in 1560.

14 "imperfecta."

15 "vitulus marinus"; Pliny (*Nat. Hist.* 11. 235 [Loeb 3: 581] and elsewhere) mentions the hairy coat, and the "generating without an egg" can be deduced from his statement (9. 41, Loeb 3: 191) that the seal is viviparous; hence it does not release spawn like a fish.

16 "cognitio."

17 "quamobrem multa generatione opus fuit."

they are sturdy, as dogs and eagles and crows do. But the most perfect, like the human being and the elephant, love their offspring almost forever. Animals that are imperfect never generate an animal from themselves — much less can they love those that have been generated. But these are generated either from eggs or from decay; as there is something perfect among every kind, some sort of generation &681 will be perfect, one neither from eggs nor from decay; many creatures generated thus are imperfect, and hence only generation in the womb can be perfect. Imperfect animals are generated either because nature could not create a more perfect one, or preferred not to. But nature cannot be grudging of good things, or fail to prefer what is good; so the remaining possibility is that imperfect creatures be generated, because perfect ones could not be. But perfect things could not be perfect from generation — this is impossible, and repugnant; hence an imperfect animal cannot be generated from perfect generation, and generation occurring out of an animal. Again, perfect generation needs more and larger resources than the instruments and faculties of the senses; this virtue[18] does not possess a corresponding function instantly in the newborn, but needs the appropriate age. Those then who have been granted the faculty of generating also have all the senses — perfect animals are like that. So as a result of this, and other reasons, no imperfect animal is generated in a womb, but this is the mode of generation of perfect animals only.

But perhaps someone would raise against us the case of the mole, which is generated blind from a mole.[19] But a mole has five senses, only its vision is impaired on account of its purpose:[20] as it lives underground, if it had[21] very sharp eyes, it would be depressed at seeing nothing[22] — it could not see in the dark. And if it were keen-sighted, it would have soft eyes, and would easily be injured by the soil on any encounter, and would see nothing enjoyable. Vision's purpose comes to an end in permanent dwellers underground, for whose sake eyes &682 were made — I mean, so that it[23] would perceive at a distance — the mole does not live in caves, but used to wear away the solid earth.[24] So it had more need of hearing; when it is compelled to live on the earth's surface to get food, it should

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[18] I.e. generation.

[19] I.e. its mother.

[20] "ratione finis."

[21] 1554 and 1560 read "si oculos praeacutos *non* haberet" but the "non" appears to violate the sense.

[22] "nil videns contristaretur."

[23] Evidently the mole.

[24] "cessatque finis in habitantibus sub terra perpetuò, quorum causa facti sunt oculi, ut scilicet à longè sentiret: ipsa verò non in cavernis habitat, sed solidam terebat terram." — the thought is confused and the syntax unclear, but perhaps Cardano has in mind that creatures normally resident permanently in caves might need to glance out occasionally.

use hearing to avoid the perils of miners and the violence of other animals. So the visual faculty was very conveniently transferred into sharper hearing—it hears extremely well. But it is not totally without eyes; it has quite small protruding dark ones, lurking under its hair. So everything that is generated out of an animal is a perfect animal, and the separation[25] of this organ[26] is now explained.

In addition to these distinctions, there are those of animals that are perfect from the form they have acquired—some without legs, some with a pair, some with a set of four. Those that have wings have generally two legs, but the bat has four.[27] There are those that have feathers. And among the fish are those that have a number of legs, but they are not properly called legs. Crabs have more than four legs. But this number is enough for the animals that genuinely possess legs. Instead of two front legs, a human being has arms and hands, in the way that birds have wings. And animals differ in the shape of the mouth, and in their skin which in some of them has hair, in others scales, prickles, a carapace,[28] feathers.

[A] There are some of diverse kind and uncertain nature, like that animal which we saw at Pavia on the nineteenth of January in the present year.[29] The size of a wolf, &683 rather longer, the face and grin of a hare, with long hair, and two very long teeth, the length of a human finger, sticking out like those of a squirrel. The eyes of a snake, since they had no angles[30] and were dark. There was a cap on its head very like a he-goat's beard, yet similar to a peacock's crest. The hair of a weasel, and beautiful, except that above the neck it resembled shiny white wool; front legs like yew trees, ears and back legs no different from the human ones, [522]except that on the feet there were bear's claws instead of human nails. On its back and the rearmost part of its spine were about a hundred projections[31] protruding, some of which were curved at their top. When the creature moved, they were creating a din while crashing together. The tail of a goose, but the feathers were terminated by spines. If you fail to see the rest, you will call it a goose, with shiny white and ashy spines like feathers, and wide buttocks reproducing those of a goose. Voice rather unclear, hoarse like that of a barking dog.

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[25] "divisio."

[26] "membrum."

[27] A bat's two wings consist of membrane spread from the front legs on each side, so it can be regarded as possessing two wings and four legs.

[28] "cortex."

[29] It is noteworthy that this date is stated identically in the 1554, 1560 and the *OO* editions! *De Subtilitate* was originally written in 1547–1549 (Maclean, *De Libris Propriis*, M81 [83]).

[30] There are angles at the human and similar eyes where the upper and lower eyelids meet each other, one beside the nose ("medial" or "greater" angle) and the other laterally; they are mentioned for instance by Galen (*On Anatomical Procedures, the Later Books*, Book 10. 5, trans. Duckworth, 51) and by Jean Fernel (*Physiologia*, Book 1, chap. 14, trans. Forrester, 151).

[31] "emissitiae."

The animal is bad-tempered, yet can easily be handled by a trainer.[32] Dogs used to pursue it with great hostility. Sex female, age juvenile. No drink; food was bread moistened with water. It is accepted that this was a porcupine, or born of a porcupine,[33] for instance mated with a bear or a monkey. Once upon a time, the porcupine was confined[34] to Africa; now France and Italy have pigs with spines, which they often project against dogs, so that perhaps this porcupine was different from the pigs; spines, however, not smaller than those of these pigs; of &684
a palm's[35] length, very sharp, light, marked with white and dark. The hedgehog has spines too, but small over its whole body, not movable, and the animal itself is much smaller than the porcupine, and curls up into a ball.[36] But good heavens, it was created for human health; by its dryness and temperament it assists the liver, kidneys, bladder, stomach, lungs. The sheep is its opposite from the region, with its very soft fleece. Barren fodder increases the fine character[37] of the wool. And so Vergil writes:

> If you mind about the wool, start by getting rid of rough woodland and burrs and caltrops,[38] and avoid luxuriant pasture.

And for that reason the English wool is now celebrated, as the Milesian wool once was. So Vergil again:

> Round her the Nymphs used to card the fleeces from Miletus.[39]

So now Britain is famous for wool. No wonder, since it produces no venomous animal, nor even an aggressive one, apart from the fox and wolf in the past; now, with the wolves exterminated too, the livestock roam in safety. The flocks assuage their thirst with the dew of heaven, and are fenced off from all other drink, because the waters there are deadly to sheep—and also because in moist fodder worms abound in plenty. The crow population has grown so much that the damage to crops has recently caused a reward to be published by the public council. for those destroying them; where there is fodder, animals are found there that feed upon it, and to excess, and then they multiply, since it is in profusion

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[32] "circulator," which classically means an itinerant performer, mountebank or quack, and is so used in Book IX at 643–44 (1560).

[33] The classical word was "hystricem" instead of Cardano's "histricum."

[34] "proprius."

[35] On the dimensions of a palm, see n. at 1080 (1560) in Book XVII.

[36] The preceding description of porcupine and hedgehog was modified between 1550 and 1554 and again in 1560.

[37] "subtilitas."

[38] "tribuli," or "triboli" in the present-day text (Vergil, *Georgics*, 3. 384) is a spiny plant, *Tribulus terrestris* or similar.

[39] Vergil, *Georgics*, 4. 334.

everywhere. As I said, it is free of snakes, for three reasons: few of them can be generated, because of the vast cold;[40] and &685 because it is very well tilled, those that are generated are exterminated. When once it had got free of them, they could not arrive from elsewhere—it is an island, and the sea is in the way.

Almost the same is the case with wolves. There is a marvel which I have heard from so many men that it would be more outrageous not to credit a lie from so many witnesses, than to preserve the truth in the face of their authority. The marvel is that if the abdomen of the wolf fish of the river (which the Italians call the pike[41]) is slit open so as to reveal the roe,[42] and then stitched together, and replaced among the tench[43] in the fishponds, the fish is healed by their[44] humour, while the wolf fish rubs itself on them with its abdomen. The reason for this is obvious, since the viscera are not damaged, and the humour itself is sticky, and air to cause corruption is barely available. And I do not know whether this would be the outcome for anyone trying it in Italy. What is the conclusion? Surely, returning to my account of the sheep, it turns out more remarkable on account of the regions, because in hot ones the tails of wethers[45] grow so huge that Johannes Leo[46] records that he saw in the city of Arsinoë[47] in Egypt one of eighty pounds weight, and people mention some growing to 150. To have grown to fifteen or twenty is ordinary. I saw one of about three pounds, so far as I could estimate without measuring.

But in our own regions, these tails usually outdo our rams by their incredible size. This happens because this animal is extremely moist and (among quadrupeds) cold. And as the other bones cannot be extended, in case the animal is overwhelmed by its own fat, it transfers all the humour into its tail, and it gets enormous in flesh and fat, and the &686 bones extend too, and the sinews[48] quite a lot—by their moist nature they are always suited to growth, as fishes are. But is it not deserving of admiration that in some wethers there are four horns, and yet we have them like that at Milan?—it is commonplace in Scotland, just as the

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[40] Scaliger differs (*Exercitatio* 200 [645]); the summers being cooler, he says, the winters are correspondingly milder. And even in Scotland, further north still, he says the people eat excellent white bread and have fertile crops.

[41] "lucius."

[42] "lac"; Pliny uses this word, normally meaning "milk," for the spawn of an oyster (*Nat. Hist.* 32. 59; Loeb 8: 500), and here it appears to mean the roe of the fish, "milt"; in English, "milt" and "milk" have however different origins, the former being linked to German "Milz," spleen, and not to German "Milch," milk.

[43] "tinca."

[44] I.e. the tench's.

[45] "verveces," castrated male sheep.

[46] See n. to 160 (1560) in Book II. The tale from Leo and Cardano's own here first appear in 1554, replacing a less precise account.

[47] Spelled "Asinoë" here, capital of the Fayum.

[48] "nervi."

Sarmatians have them with six or eight—rarely with five or seven, the number being uneven—sometimes even with a single horn, but not a central one.[49]

And these are lesser miracles than Aristotle reports, that a she-goat[50] was seen with a horn on its leg.[51] This undoubtedly occurs through an error of nature, and through excess or deficiency of matter suitable for the generation of horns. But because their head is weak, in these animals nature thought it better to split the load than to weigh the wether down harmfully.[52] It sometimes happens that a ram is born with a single horn in the middle of its forehead, as occurred in the villa of Pericles while he was presiding over the affairs of the Athenians.[53] The seers predicted coming general confusion, and reduction in the city's power—and rightly, because two things distinct in nature have coalesced into one, with a reduction in the number of weapons, and this had occurred in the villa of the man in charge of the city. This took place precisely: initially with the disastrous Peloponnesian War, which was followed by famine and then a very ferocious plague, and finally by slavery too. But Anaxagoras[54] covered up the event skilfully, persuaded I believe by Pericles, who was his disciple; he said that it had happened because the cerebral ventricles[55] had coalesced into one. And when the animal was dissected, he showed that this was so. But if this was the sole reason, it was proper for the horn to be born in its own time, not when the ram was born. &687 Next: there is nothing to stop errors of nature having their own causes, and providing premonitions of the future. And so, as is true of everything else, the oscillating reciprocation of Philosophy leads to both the destruction and the salvation of the human race. This makes me less astonished that at one time Nero expelled the philosophers from Rome, as we said in our *Encomium of Nero*;[56] through some people's greed, wisdom is less health-giving than destructive; and in an evil mind, Philosophy is nothing but a sword in a robber's hand—what

[49] Cardano had travelled to Scotland in 1552 to treat Archbishop Hamilton there. He first inserted these reports of places where this anomaly was found in the 1560 edition. See Dana, "The History of a Great Consultation: Jerome Cardano goes to Edinburgh." Also see C. Lavers, *The Natural History of Unicorns* (London: Granta, 2009).

[50] "capra."

[51] Aristotle, *On the Generation of Animals*, 4. 4; Loeb 427.

[52] Material from here to [B] on 696 (1560) is new in 1554.

[53] "A story is told that once on a time the head of a one-horned ram was brought to Pericles from his country-place, and that Lampon the seer, when he saw how the horn grew strong and solid from the middle of the forehead, declared that, whereas there were two powerful parties in the city, that of Thucydides and that of Pericles, the mastery would finally devolve upon one man,—the man to whom this sign had been given" (Plutarch, *Pericles*, 6. 2; Loeb 3: 15).

[54] See n. in Book II at 148 (1560).

[55] "Ventres"; the conventional word for these cavities is "ventriculi."

[56] Cardano's *Encomium Neronis* was written in or before 1557 and published in 1562 at Basle (Maclean, *De Libris Propriis*, M94 [92]).

good does a Philosopher contribute, instructing princes and peoples that the universe is eternal, the soul[57] mortal, God's [523]providence non-existent?[58] Is it not as if he were to say, suppose you are an overt usurer, an adulterer, an assassin, a poisoner, a traitor, work your way through all the crimes—all right, so long as it is kept under cover? Well, the foolish ram advised it.[59] The twofold wisdom of the Athenians (the leader's wisdom, and the Philosopher's) overturned their fatherland. Do not be astonished that I said the ram is foolish; creatures with cloven hooves are all more simple-minded than those with a single foot,[60] and those with a single foot than those that have toes on their feet. One particular distinguishing characteristic of animals is drawn from the nature of their feet: some have a single foot, some have twin hooves, some have toes. Some with a single foot are sturdy, but not tolerant of work, like horses; some are tolerant of work, but not sturdy, like donkeys; some tolerate work and are sturdy, like camels. To make donkeys quite tolerant of work, they were created stupid. When drinking, they dip their muzzle in sparingly, because of the shadow of their ears—they see it &688 very large in the water, and are frightened, in case the water wets their ears, and the shadow of their ears impinges on their eyes. Further, this animal is dry by nature, and hence no friend to water. A female donkey carries its offspring for a year, because a male one can live thirty years, although its hard work rarely permits it to reach its proper lifespan. It shares with the horse, the male and female deer, and indeed the camel too, the feature of lacking bile—however, the

[57] "animus."

[58] These are three views deriving ultimately from Aristotle, but more usually associated with his Andalusian commentator, Averroes: views already under intense contention since at least the 13th century, the epicentre being Paris. From the stance of the Catholic Church, Cardano is addressing (but not endorsing) seriously heretical views. The first view is in conflict with the Genesis story of the Creation of the world, and therefore with Church orthodoxy. In 1517 a Lateran Council of the Church authoritatively condemned the second view. The Council denied that the intellective soul is either mortal or "only one [soul] for everyone." On these views and their link with Averroes the Arabic authority on Aristotelianism, see http://www.muslimphilosophy.com/ip/rep/B012.htm. Averroes was the most famous of the mediaeval Islamic philosophers, born in Córdoba, Southern Spain. He was a judge successively at Córdoba, Seville, and in Morocco, and wrote on jurisprudence and medicine. In 1182 he became court physician to Caliph Abu Yusuf, but in 1185 was banished. His *Commentaries on Aristotle* were his most important works. And on Pietro Pomponazzi (1462–1525), a leading Averroist in Italy shortly before Cardano's time, with highly developed positions on such issues, see http://plato.stanford.edu/entries/pomponazzi/. Lindberg (*Beginnings of Western Science*, 234–44) is also very informative on the interrelation between the Church and views such as Cardano mentions here.

[59] "aries stultus consuluit."

[60] "solipeda."

camel has the point unsettled.[61] The reason is that they have drier flesh, and flesh more tolerant of work. Horses are more noble-spirited than donkeys, but less dry, and hence less tolerant of work. What people call Barbary horses originate in Africa,[62] and are very swift because of their training. They bring forth mares that grow wild through fear of wild beasts and exercise themselves daily. Their offspring are therefore snatched away and are nourished with camel milk; and when they have matured, with straw and stubble. Thus they become very swift, because of their food and the air and exercise. This would happen in our regions too, but after a number of generations. On a diet of doe's milk too they would make good progress, for nutrition changes souls, let alone bodies. This animal has a perception of glory and of its obligations. It is said that in Ireland the horses are so well-conducted and docile that they adjust themselves at the part where they can better accept the rider. Evidence of the sagacity of horses is their great affection for their offspring; no animal is so fond of its sons as a mare is of its foal. The length of their life is indefinite, because of the work they do; some of them among us have even reached fifty years, but they rarely exceed thirty. The mares live longer. Aristotle recorded a mare that lived to the age of &689 sixty-five.[63] These two kinds of animal are confused because of the resemblance of their nature, as if there were a craftsman looking after humanity's advantage; and there are mules created with the tolerance of donkeys and the strength of horses. Wild donkeys, called onagers, are more common than wild horses, whose flesh is esteemed as food; even the flesh of domesticated donkeys approaches that of calves, so long as the donkeys are young—it is not sticky and abominable like horseflesh. Good heavens, people are wrong to call "wild donkeys" the animals armed with long horns and a mane and deformed in other respects, called bison[64] elsewhere. Thus they could not be more numerous than three in respect of kind, but in respect of species there is no obstacle; Aristotle records that there are also fertile mules of a kind of their own in Phoenicia,[65] and among them there can be more or less either of liveliness and strength and agility, or of tolerance for undertaking work.

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[61] "indiscretum"; Pliny (*Nat.* 11. 191) simply says they have no bile.

[62] The "Barb" breed of horse is a sub-breed of the Arab.

[63] There may be some confusion here. In *Historia animalium* (5. 14; 545b16–20; Loeb 2: 139) Aristotle wrote that "the stallion normally lives to about thirty-five, the mare to beyond forty, though a case has been known of a horse [male] that lived to be seventy-five."

[64] Pliny mentions the bison (*Nat. Hist.* 8. 38, 28. 159), but not the horns nor the deformity.

[65] In *On Marvellous Things Heard* (69) Pseudo-Aristotle wrote that in Cappadocia they say that mules breed. Aristotle himself (*De generatione animalium*, 2. 7 and 8; Loeb 245 and 259) is emphatic that mules are sterile, and makes no mention of Phoenicia, but finally states that a male mule may be able to procreate with a mare.

But the camel is the most outstanding of all. The African one has one hump or bulge, the Bactrian two—I know both species. And the African ones are almost like donkeys in colour, the Bactrian ones rusty-coloured. Camels are not properly single-footed, but virtually cloven-footed, nor precisely so, but the foot displays a slight impression of five toes, fleshy in part of the sole, and so no use to those journeying among rocks. But—an extraordinary thing—since it does not have horns, it is alone in lacking the front teeth of the upper jaw, like the deer and the ox. It also ruminates as they do, which is essential: animals do not ruminate because of having horns, but because they lack the upper &690 front teeth, which the camel too lacks.

It passes urine out to the back, because it has a rear-facing genital tract. It chases horses with a natural dislike, and is almost of an elephant's height, but this is because of the length of its neck—this is also how the bird called "ostrich" got its name.[66] The camel's whole body is more slender than that of the horse, its head small, its eyes large and prominent. Its muzzle,[67] if I may so call it, is like that of oxen. But they differ quite a lot from one to another, and particularly in size, so much so that on this basis three kinds are listed. The largest with one hump are called "Hugium," the smallest "Raguahil," and they traverse a hundred thousand paces a day; they are very lightweight, and better suited to travel than to load-bearing. Camels run faster than the Nissan horses, because of the length and wide spacing[68] of their legs.

The middle kind are called "Becheti," with a pair of humps. But best of all are the African ones; these are drawn from the Bactrian ones. They drink every five days, and if they drink sooner, they get damaged. They tolerate thirst up to fifteen days, both from practice, and because the animal is dry, and because nature has taken proper care that an animal living in deserts has minimal need of frequent drinking, where drink is rarely available. Likewise, it is very tolerant of hunger. When it does happen to get thin, first of all the hump and the back thin out, because of the load and the sun, and then the abdomen, because this part is softer and is rich in abundant heat; finally the legs, and then it is already in distress.

Its flesh is very tasty, and its milk very tasty and healthy. But like wine, it is drunk mixed with an &691 equal weight of water, or even twice as much. The animal dances to the flute, and seems to enjoy music, but the skill and the practice[69] matter more than a sense of harmony. However, when it tires, singing stimulates it to pursue the journey spontaneously. When young, it is placed

[66] "Struthiocamelus," more conventionally "struthocamelus," στρουθοκάμηλος, means "sparrow camel." Cardano's remark here first appears in 1560, an edition in which the next three sentences are revised and amplified.

[67] "rostrum."

[68] "distantia."

[69] "ars et usus."

on a hot pavement, while someone is playing on a flute or cithara, and the camel lifts up its feet because of the heat; in this way it pays attention to this performance daily. The mode[70] conforms to the lifting of its feet. When a year has been passed in this pattern,[71] the camel lifts its feet with the rhythm, even on cold ground— this is the way the camel learns to dance.

But what is remarkable about the [524]camel—I called it a skilled animal—learning an accomplishment, when the donkeys themselves dance to the flute, and lie down on their backs spontaneously when a voice whispers in their ear? With their eyes closed too, they puff themselves out as if they had drunk poison, and cannot be induced by threats or blows to consent to get up. But with flattery and blandishments, and the prospect of carrying beautiful women, they get up quickly and eagerly—but when they have heard that old women are to be carried, they lower their ears and limp. Again, if you ask them whether they like beautiful young females, they nod their heads. Finally, in a crowd around them they pick out the most handsome man. So this Egyptian donkey seems little different from Lucian's famous one.[72]

But the tale that Leo Africanus[73] recounts is true, that in a suburb of the city of Cairo named Bebelloch,[74] he more than once saw itinerant entertainers[75] scrape down a large tree trunk with this skill[76] almost every day of Venus (this is a Mohammedan festival corresponding to the Jewish Sabbath and the &692 Christian Sunday).[77] To teach a donkey should not seem such a marvel, because the sensory part[78] is capable of every use. And a donkey is itself endowed with a

[70] "modus"; this might mean the musical *mode*, since these were of contemporary interest; Henry of Glarus (Henricus Glareanus) in his *Dodecachordon* of 1547 initiated the theory that instead of the traditional eight modes of Church plainsong, there should be twelve. But probably this is not the meaning of "modus" here, because these modes are sequences of notes of specified pitches, and not rates of performance. See S. Boynton, "Modes, Melodic," *Oxford Dictionary of the Middle Ages* 3: 1152–53.

[71] "forma."

[72] Lucian of Samosata (c. A.D. 25–190), a Greek satirist noted for his wit and the elegance of his Greek, in his "Lucius or the Ass" told of a donkey capable of enthusiastic coitus with women.

[73] Leo Africanus (*History and Description of Africa*, 3: 874–76) recounts a marvellous and detailed story of a donkey trained to feign death and delight, and it even espies "some woman more comely and beautiful than the rest, walketh directly unto her and toucheth her with his head; and then the onlookers laugh and crie out amaine: Lo, the asses paramour . . ."

[74] Bab el-Luk.

[75] "circulatores."

[76] The "scraping of the trunk" is not a phrase used by Leo in the original account, and may indicate how the entertainer fleeced his audience.

[77] In fact Friday, not Sunday, is the day corresponding to Venus in Islam.

[78] "pars sensibilis."

sensitive soul. The claw in a crab[79] shows this—it is moved in so many different ways, without any thought, for use alone. How things reached this stage little by little can be appreciated from what has just been said about the camel and what will later be said about the dog. The whole art of teaching animals consists in two parts: practice, and the combination of actions.[80] And so it is accepted that the single-footed animals are more sagacious than the cloven-footed—and among both the single-footed and the cloven-footed, the camel is outstanding. Hence someone will have good cause for uncertainty which should be called the more perfect animal: the dog or the camel. Indeed, if we consider length of life, the camel is closer to man than the dog: the camel lives sometimes a hundred years, the dog's life is ended in its twentieth year. Hence Homer is regarded as having been right to represent that the dog of Odysseus died in the final year.[81] But as the camel rarely reaches its sixtieth year, so the dog more rarely reaches its fourteenth. Camels too enjoy music, dogs barely at all. But dogs are more responsive to training. So I would have said that the moistness of the camel is fattier, and the substance of the dog is more rarefied, and for these reasons the one is closer to man than the other is.

But yet another uncertainty arises: since it looks as though the camel is actually created at any rate more for the sake of man, not for its own sake—yet no one who has read what we have written below doubts that &693 this is false—but it does seem to be completely the case; what is the point of those humps on the back, unless to carry weights? What is the point of four knees, since the horse and donkey, and oxen and deer too, have only two? Camels bend their back legs forward, and they are curved backward like human legs, and like the front legs of horses. What is the point of that protuberance on which it sits, placed underneath while it is bent onto its knees?[82]—unless so that being very long-legged, it could be bent onto its knees while taking on a load? And so in view of their easy intimate association[83] with us, if in fact there is an animal made for the sake of man, the camel and the dog appear to have been generated for him.

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[79] Cardano has written, "ostendit hoc in cheli manus," where "cheli" means a claw (classically "chela"), but I assume that he has conflated "the claw in a crab" with "the hand in a crab" to produce this text.

[80] "actionum concursu" in 1560, "synergia" in 1554.

[81] "extremo anno"; the dog Argos recognised his master Odysseus returning after many adventurous years away, and then died at once "in the twentieth year" (*Odyssey*, 12. 326–327).

[82] The camel has "flat, leathery, localized pads on the volar carpal surface, elbows, knee region and sternal [i.e. under its chest] region, and they enable the camel to lie down on hard, uneven surfaces without injuring its skin or the underlying muscles." http://www.fao.org/docrep/X1700T/x1700t05.htm, accessed on 28 March 2008.

[83] "convictus facilitatem."

Yet, as I said, it is ludicrous to believe such things; it is better to suppose that a camel is made humped because being an animal leading a solitary life, that part full of humour would contribute a great deal to endurance of thirst and hunger. The evidence is that in human beings too a hump generally develops through unrefined humour, and because (as mentioned) while a camel is exhausted by hard work, hunger and thirst, it will thin out first of all at that part. The reason for the knees and the forward or lower hump was that the camel was destined to have long thin legs and was forced to make a long journey, and during its existence in dry and uncultivated places to search for food and drink, needed rest, which it could not safely obtain by lying down as donkeys and horses do. This is why it takes rest lying on its knees and its protuberance below. When it sits, this animal is arranged &694 as a human being is.

So these features were not created for the sake of man, but of the camel; nature must surely be over-anxious if it has created so many major arrangements in this animal for it to carry a burden for so short a time, while a human being could make up for deficiency of height by common sense,[84] stools, ladders, and other methods. So the forms that are peculiar to animals are really to meet a peculiar application.[85] But someone will say: "Why do all these outstanding animals have a form very different from the rest?—for instance, human being, elephant, camel, crocodile, and among the fishes the dolphin?" It is beyond doubt that these are the most distinguished of animals, provided only that a human being is entitled to be called an animal. The reason for this is threefold: first, because these animals ought to be long-lived if they are to be perfect—and hence endowed with moistness much mixed with fattiness. They could not acquire powers from their temperament, but they were in need of them, so that a refined form was required. The second reason is that an extreme lies further from the midpoint than midpoints lie from each other; the extreme is double the midpoint, or more than double. And the extreme is the most perfect, on account of being furthest from the others, and thus is seen as possessing a special form. The third reason is that since the most perfect animals assemble advantages of many kinds, they therefore appear to stand in the middle of these kinds, and hence assemble a special form of their own. The camel evidently is midway between the cloven-footed and the single-footed, and though without horns, is very like the horned animals; it has its special hump as well as that. &695 The human being lies between the two-legged and the four-legged creatures, but is hairless, and this is a special property of his, not adopted from some other animal—unless you bring in the snakes or the fishes; either he is far removed from their nature, or he puts on the nature of all, having in fact a share of them all. The crocodile is midway between the fishes and the quadrupeds and lizards. Its particular char-

[84] "prudentia."
[85] "commodum."

acteristic is moving its upper jaw and keeping the lower one fixed.[86] The elephant is midway between the horned animals and those without horns, which have toes on their feet, and are single-footed, as [525]it has acquired its special trunk. And if we can mention its teeth,[87] they are huge, and externally prominent. I say the same about the dolphin.

But now my account is off in another direction, and would not be held up if this one issue I have just mentioned were not presenting itself: why mules are sterile. This wearies Aristotle and the rest of the philosophers, but we do not labour much at this problem; it was stated above that animals with imperfect generation are sterile. But since the seed of horse and donkey[88] differ such a great deal that they are at the extreme limits of those that can combine for generation, it is evident that what is generated from their mingling is sterile. Less sterile than these are the Indian dogs which are generated from a tigress and a dog, and less still the wolf-bitches[89] born of a bitch and a wolf. Likewise the "laconici"[90] born from a fox and a dog; being little different from their parents' nature, these are prolific, and change over into the other look[91] of their parents in unbroken succession. This certainly could not occur if they became sterile for a reason of their own acquired from their parents' difference.

&696 But as I said, there is this common cause for everything procreated by imperfect generation, whether this is from decay or from a great discrepancy between the male seed and the female blood. Hence this is reckoned the general cause of sterility. If in fact the seeds of the male and the female have been within the bounds of the temperament, generation takes place, and what is born is fertile. But if both seeds have existed with contrary qualities, they will generate, but what is generated will be sterile. But if they suffer from a like abnormal temperament, they will not generate. There are also sterile males in which the penis does not erect.[92] They are born of aged parents, if this occurs by nature. There are some people in whom the seed is faulty, for instance in those whose testicles have been extracted. So the species are altered by this mingling, and they stop existing.[93]

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[86] See n. in Book IX at 664 (1560).

[87] Tusks.

[88] The underlying contemporary belief was that male and female seed combined for reproduction. See for instance Jean Fernel, *Physiologia*, Book 7, chap. 6, "The female's semen" (trans. Forrester, 553–59):

[89] "lyciscas"; the word appears in Vergil (*Eclogues* 3. 18), and in Ovid (*Metamorphoses*, 3. 220) it is a proper name, of one of Actaeon's hounds.

[90] Aristotle (*Hist. animal.* 8 (9); 608a27–28; Loeb 11: 217) refers to the breed ("for example, the female Laconian hounds are in fact cleverer than the males") and earlier (607a2) mentions their origin from a hybrid of fox and dog.

[91] "species."

[92] This was a problem for Cardano himself. See n. to 370 (1560) in Book V.

[93] Eckman (*Jerome Cardan*, 77) points out that despite this remark, Cardano cannot be regarded as a significant forerunner of evolutionary theory.

The elks which were certainly in being in Caesar's time were possibly of this kind; but now it is uncertain whether they exist and what they are.[94] Similarly in the time of Pausanias there were Indian camels entirely like a leopard in their colour and its diversity;[95] but now they are either non-existent or very rare—the generation and nature of any imperfect animal is inconsistent, as I said.

But now it is time to move on from this to the kind of the more perfect animals, which have toes on their feet, not hooves. The more perfect ones will give us a start. Within this kind, the dogs are more perfect, and had their origin long ago from the wolves. [B] When they become wild, first they change into untamed[96] ones, then into wolves—similarly, over many generations domesticated wolves change into dogs. &697 Hence for the lycisca, produced from wolf and dog, the difference of voice is no problem, since on the island of Hispaniola in the West Indies the dogs are totally mute although capable of howling more[97]—and although some domesticated dogs howl, even if this is reckoned one of the marvels.[98] A piece of evidence that dogs are of the wolf kind is rabies, a disease common to both and very destructive; but in the wolf it is even more serious, and totally untreatable, so much so that a rabid wolf has killed as many as sixty animals of diverse kind, among which there were more than twenty human beings—no one nor any animal injured by it escaped, since even a horse barely scratched by its claw, not by its teeth, perished—except a man whom it had exhausted with many wounds. I think the reason was that he had lost a lot of

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[94] Caesar, *Gal.* 6. 27 sect. 1: "There are also animals which are called elks. The shape of these, and the varied color of their skins, is much like roes, but in size they surpass them a little and are destitute of horns, and have legs without joints and ligatures; nor do they lie down for the purpose of rest, nor, if they have been thrown down by any accident, can they raise or lift themselves up. Trees serve as beds to them; they lean themselves against them, and thus reclining only slightly, they take their rest; when the huntsmen have discovered from the footsteps of these animals whither they are accustomed to betake themselves, they either undermine all the trees at the roots, or cut into them so far that the upper part of the trees may appear to be left standing. When they have leant upon them, according to their habit, they knock down by their weight the unsupported trees, and fall down themselves along with them." (Translation is that of B. Greenough, Benjamin L. D'Ooge and M. Grant Daniell, *Commentary on Caesar's Gallic War.*) Pausanias (*Description of Greece*, 9 (Boeotia), 21. 3; Loeb 4: 261) mentions that there is a beast called the elk (ἄλκη), in form between a deer and a camel, which breeds in the land of the Celts.

[95] "I saw Indian camels with the colour of leopards" (Pausanias, *Description of Greece*, 8. 21. 2; Loeb 4: 261). Diversity is not mentioned. "Camelopard" is an ancient English name of the giraffe.

[96] "agrestis."

[97] "quandoquidem in occidentalis Indiae Hispana insula canes ex toto muti sint, quantò magis ululare possunt."—syntax unclear.

[98] From here to the end of paragraph is new in 1554.

blood.[99] Rabies is a disease proceeding from dry decay; hence it is more aggressive in a wild animal, one already spontaneously drier. But all rabies is incurable once the victims have reached fear of water.[100] Hence Ovid wrote: "None with the dread of waters is healed."[101]

The dog copulates with the fox and the tigress, with common sons that reproduce the form of both. They can copulate provided the periods of gestation in the womb fit, as was mentioned in the case of trees,[102] and provided a common food exists. The "alopeca," the product of a dog and a fox, which I have seen, was male and mute; I do not know whether they all are. This most talented animal appears to associate deliberately with a human being, since nature always strives to link like with like, and the resemblance of their habits begets and preserves friendship; a dog would be &698 hard on a human being unless nature were so cunning; the dog is loved for its scrupulousness and talent, which commend it. In Corsica they are very fierce and strong and big, both on account of the air (in moist air, what is naturally dry grows large) and on account of their exertion and training. They have a very big head in comparison to their body, which is large too. Food, fighting, the air, their training, their nature alters them so much that they seem to differ in species. They are trained to detest some kinds of people, as at one time the dogs of Rhodes were trained to hate Turks, and the Bezerillo[103] to hate Indians. This was the dog that could distinguish Indian people from Spaniards, according to Gonzalo Fernando Oviedo.[104] They are greatly maddened by human flesh, and have supernaturally sharp senses; so that this dog was trained to lead along those who are willing, to mangle those who refuse, and to spare those who have fallen down. What these people credit[105] to God's will and indulgence, I put down to feeding on human flesh, or to practice, or rather to demonic aid. Nor have I convinced myself that such cruelty is pleasing to God. This dog was able to understand the language of those who are fighting and that of those who are recoiling, having learnt to attack and mangle and drag along those pointed out to it by finger or by name.

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[99] This may mean that the man died quickly of his wounds, rather than slowly of rabies; or alternatively that he survived, and the poison was regarded as voided from him with the shed blood.

[100] The other name of rabies is "hydrophobia," the deadly symptom of fear of water.

[101] In his *Epistulae ex Ponto* (1. 3. 24) Ovid wrote "nec formidatis auxiliatur aquis," not Cardano's "nec formidatis ulla medetur aquis" here.

[102] Reference not traced.

[103] A fighting dog of the bulldog type, used in the conquest of Mexico (by Spain, in the mid-sixteenth century) (*Enciclopedia Italiana* [Milan and Rome: *Instituto dell'Enciclopedia Italiano,* 1930–1939]; 8: 720b).

[104] See n. on 128 (1560) in Book II; I cannot identify this tale in Oviedo's *Historia general y natural de las Indias.*

[105] "transferunt."

The Rosomacha in Lithuania[106] teaches us that animals are born, virtually in single districts, which resemble people in their ways—for instance the animal named the wolverine,[107] with the size of a dog, the face of a cat, the back and tail of a fox,[108] rough and tough feet and claws, and teeth too. So much so, that dogs with no fear of wolves keep away from them. Its skin is white with a mix of tawny, and it displays various shapes with extended lines. One can see &699 the like in the cloths which are imported from Asia and called Zambeloti. These are reputed to be made from goat hair, with wavy work. Nature has contrived such shapes in wolverine hides, which hold on to heat when they have taken it up; they take it up instantly, which is why it is apparel for princes, on account both of its beauty and its scarcity—though they do initiate wild dreams;[109] they [526]appear setting ambushes, and being gluttonous, and fear upsets them. In fact, foods generate dreams according to the quality of their nature—the odorous foods usually provoke fires, the sweet ones provoke waters—and similarly, wolverine hides provoke humours and vapours. In addition, when their hooves are worn, they lead to tinnitus and giddiness. When fresh in odour or appearance, they terrify dogs and cats. A magical power is thought to be present in their teeth. Their lard[110] is effective in healing all wounds. At weddings, people drink

[106] From the entry "Corocotta" in "Martin and Oliver's *Dictionary of Ancient and Mythical Entities, Beasts, Creatures and Monsters—Benign and Otherwise*"—"The result of cross breeding a hyena with a lioness. This odd badger headed, donkey sized animal, whose physique was a combination of stag and lion, was able to mimic the voices of men. Its gaze was permanently fixed—probably as a result of possessing, rather awkwardly one would imagine, a rigid spine prohibiting any chance of the thing looking over its shoulder. It had cloven hoofs and in place of teeth, the creature also featured one single bone-like tooth extending right round its jaw. Also called variously: Akabo, Alazbo, Corocotta, Crocuta, Leucrocuta, Leucrota, Rosomacha and Zabo." See http://www.finestoneminiatures.com/zoo2.htm, accessed on 4 September 2006. See also Anna Maranini, "Le glouton et les éditions de la Renaissance," *Faventia* 26 (2004): 111–22. She takes Rosomacha to mean wolverine. Scaliger (*Exercitatio* 203 [653]) says the Rosomacha is synonymous with the German Wildfrass (not identified), and searches for carrion.

[107] "Gulo"; the scientific name of the wolverine (or "glutton") nowadays is *Gulo gulo.* Olaus Magnus (see n. at 637 (1560) in Book IX; *Description of the Northern Peoples*, book 18, chap. 7) described it thus: "He is as great as a great dog, and his ears and face are like a cat's: his feet and claws are very sharp; his body is hairy, with long brown hair, and a fox's tail, but thicker, and of this they make brave winter caps. Wherefore this creature is the most voracious; for, when he finds a carcass, he devours so much, that his body, by over-much meat, is stretched like a drum, and finding a narrow passage between trees, he presses between them, so as to open his bowels forcibly; and this being emptied, he returns to the carcass and fills himself full."

[108] The remainder of this sentence with the following twelve sentences first appears in 1560.

[109] "Quamvis somnia fera immittant."

[110] "adeps."

their blood mixed with honey and water; it is unclear whether this is instead of nectar or of an amulet. In lyres, strings made of their intestines give out a coarser tone. The animal is so greedy that when it feeds on corpses, and its stomach is entirely full, it squeezes out what it has eaten from its bowel between two trees slightly separated, and then goes back to cramming itself. Thus the Lithuanians are the most voracious of men.[111] Either the hide is like this in potentiality, and is brought into actuality by human heat; or this happens when the stomach is chilled—the stomach can hardly be sated when overflowing with a great heat and with a little.[112]

But to return to the dogs: no animal is so docile. It is taught to hunt, to search, and to carry. To be talented, it ought to be dry.[113] &700 Those that have the head rounded and the nose quite lowered are more talented. They are taught to turn a spit, as in the inn of Leo of Pavia—you can see several there that have been instructed. Nature gave them a very keen sense of smell; so the large ones are suited to hunting, the small ones fawn upon their masters on beds and furtively.[114] Where a cat has been buried, or if they find its dry skin, they go round and round it; they enjoy the smell of the dead creature which they hated in life. But they run from a rotting one—the smell of dry rotten flesh upsets them and all[115] human beings. The animal is short-tempered, and as given to quarrelling as human beings are—it runs up to join a fight, and chases and hounds fugitive and noisy ones, even those entirely unknown to it. They howl at the noise of bells and the blast of trumpets and the braying of wild donkeys and many other loud sounds; the howling is their weeping, on account of their intolerance of anger. This is the reason too for their baying and howling while gazing at the Moon, because they suppose that she despises them, and take it ill—boys and women wail in the same way when they cannot exact retribution for their wrongs. As their penis is bony,[116] they lift their leg when urinating, so as not to sprinkle their belly with urine. The evidence is that neither bitches nor puppies do this; the bitches have no penis, and puppies do, but such a soft one that it can bend towards the ground, and so they do not foul their belly when urinating. They are of such sagacity that they separate off from the others the tired stag fleeing in

[111] The following sentence first appears in 1560, replacing a different one in 1554 and without counterpart in 1550.

[112] "ventriculus enim calore plurimo atque exiguo abundans vix satiatur."—the sense is unclear.

[113] The 1550 edition now discusses rabies, inserting a portion of 697 (1560) later included in the 1554 edition, with an Ovid quotation, then proceeds to 701 top (1560).

[114] "obscuro."

[115] Reading "omnibus" for the "omnis" of 1554 and 1560.

[116] This is not in fact the case.

a herd,[117] so that they can more easily catch the tired one by harassing and tormenting it.

&701 They hunt almost spontaneously, and are trained to reconnoitre. Some search out birds by scent, and these are called keen-scented[118]—ordinary people call them "brachos." Others chase hares and deer, and they primarily retain the name.[119] There are also net dogs, which terrify partridges and quails by their gaze, till they are taken in the nets. A characteristic common to all dogs is to guard their home, to bark at visitors, and to chase the poor and people in torn clothing. They are taught gradually to carry things, first by throwing a piece of bread, but in such a way that the dog is made to obey someone in command and calling it to him. Later, the bread is shut up in a box with a nail, so that when the hungry animal has made for the bread, it brings the box when called, so as not to leave the bread behind. The bread is gradually freed from the nail, so that in the end with practice the dog brings back the box with the nail tenaciously held. Finally it brings back a piece of iron, and in the same way stones, and anything very difficult. Ultimately a wooden panel[120] is placed in water with the bread, then a nail with bread; with the same care, bread is added to a nail fastened on a wall, so that the dog keeps on trying till it has extracted the nail. In all these cases, what is needed is hunger as the teacher, as in that sentiment of Persius: "the belly—an expert at copying sounds denied by nature."[121] Over a period of six months I trained a dog so well that no boy could appear more docile, or more responsive to commands, since it could understand the very nods. And though it could all be classified under the industry of the learner, dogs are chosen nevertheless that are hairy, and with hair far from straight, but thin and soft, and flowing downward[122]—they seem more talented, and more tolerant of hard work, and more obedient, and less given to barking, like the more popular ones from Mljet,[123] which however are useless because so small. There is no &702 fixed size of dog, nor talent, nor a single colour, nor a voice. Some are almost as big as an ox, some no larger than a mouse, some are mute, some noisy, some even howl. Reddish, shiny white, brownish,[124] dark, motley,[125] some fat, some good runners,

[117] "In gregem fugientem" when "in grege fugientem" would be expected.

[118] "sagaces."

[119] Perhaps the name of "hare hounds" and "deer hounds."

[120] "tabella."

[121] "Venter negatas artifex sequi voces,"—though 1554 and 1560 read "aedi" instead of "sequi." The quotation is from the *Satires* of the Roman satirist Persius (A.D. 34–62), at Prologue 11 (Loeb 45).

[122] "pronus."

[123] "melitei gratiores"; the "meliteus" was a breed of dog not from Malta but from an Adriatic island now called Mljet (*OLD*).

[124] "russi."

[125] "varii."

some lean, some rough and ready and virtually uncouth, some tame, cruel, some fierce, some timid, and indeed ready for anything, whether strong in their senses or in their talent.[126] So, to sum up, there is nothing that in its way of life and variety imitates the different types of human being so well as the dog.

But there are people who prefer elephants or monkeys to dogs, for their hard work and sagacity. Arrian reports that he saw an elephant which had two cymbals in its ears, [127] and used to touch them alternately with its trunk according to the rhythm, and used to dance to the rhythmic sequence, with others imitating it and leading the dance. These same creatures are sensitive to pity, and revere a king, and recognise and enforce an oath, and worship the stars, and feel distress for themselves; they recognise their driver,[128] and extract vengeance from those who have harassed them unfairly, and appear to fall short of humanity only in lacking speech, since many human beings appear more savage than elephants in their practice and their movements.

We[129] have seen a fairly young elephant (belonging to Queen Maria of Bohemia, daughter of the Emperor Charles the Fifth), evidently thirteen years old; they are in their prime around their sixtieth year, and certainly live for two hundred years. There are many reports of their reaching three hundred, and I believe it, but it is not common. Similarly, though as a rule eighty &703 years is a very long life for human beings, some in very rare instances reach a hundred and twenty, and a number exceed eighty. This elephant was so tame that it understood its driver as well as another human being could. It used to make demands on him, and warn him; in a word, it was an achievement.[130] Among other feats, when he wanted to climb up, it would bend its [527]right leg, and raise it so that he could move up gradually. When the stick used to control it fell down, it picked it up in its trunk and presented it to its driver, of whom it was so fond that when warned that he was going off to hide in a larger lodging, and then someone said, "Find your driver," it went straight to him and found him, and would fawn on him wonderfully. When the Archbishop of Milan was present, it was informed, and greeted him by inclining its front legs and head. When he said, "Say something," it bellowed.

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126 "ingenium."

127 Not in its ears; "I myself have seen an elephant actually clanging the cymbals and others dancing; two cymbals were fastened to the player's forelegs, and another on his trunk, and with his trunk he rhythmically beat the cymbal on either leg in turn; the dancers dance in a circle; raising and bending their forelegs in turn, they too kept in rhythm as their cymbalist gave the beat" (Arrian, *Indica*, 14. 5–6; Loeb 2: 347).

128 "sessor." Could be translated as "mahout," an Indian term.

129 The following account of the elephant first appears in 1554, extensively revising that of 1550.

130 "vno verbo opus tantùm erat."

But it is a good plan to describe its form with precision. First, its height was so great that a man with upstretched hands would not reach its back, and it was (as I said) a young one. The breadth of two oxen. But in adults and very large elephants, the body mass is sometimes equivalent to that of twenty-five oxen; in elephants, as in horses and other animals, there is a significant distinction between regions and ancestries. In very large ones, the height reaches ten cubits,[131] which can also be estimated readily from the size of the tusks; in this one, of the size mentioned, the teeth were in fact no more than a cubit and a half, although I have more than once seen tusks which almost reached six cubits, and were crooked inward[132] too—&704 if they had been straight, they would clearly have been longer than seven cubits. Ludovico de Varthema[133] recounts that he saw two which equalled 325 pounds in weight. Anyone can ponder how large the size of that animal would need to be.

But I return to the sequence: an elephant's length corresponds very little to its height; it is in fact much higher than its length indicates.[134] It has rounded legs, on the pattern of pillars, and with joints in them. Its hips run straight down, and are not extended forward as they are in oxen; and this happens because the knee joints have an unbroken outline,[135] so unbroken that without seeing the legs bend, you would think they had no joint. I think this is the origin of the belief that it lacks joints,[136] a suspicion increased by its gait[137]—it walks with extended legs, as if it entirely lacked joints. Its front legs are longer than the rear ones. Furthermore, the special gait it has with extended legs suggests great strength, and enables the gait to be faster—it moves with more difficulty because it does it from a longer interval—as in the case of spears, which are propelled[138] with greater difficulty from an end than from the middle—and an equal angle

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[131] See n. in Book I to 26 (1560).

[132] "incurvus."

[133] Ludovicus Vertomanus; Italian traveller and writer (1480– floruit 1502–10). He was perhaps a soldier before leaving Europe near the end of 1502; early in 1503 he reached Alexandria and ascended the Nile to Cairo. From Egypt he sailed to Beirut and thence travelled to Tripoli, Aleppo, and Damascus. First European to enter Mecca. The report of 2 elephant tusks weighing 325 lb. is in *The Travels of Ludovico di Varthema*, trans. J. W. Jones (London: Hakluyt Society, 1843), 241.

[134] "pro longitudinis ratione."

[135] "aequales."

[136] Strabo (*Geography*, 16. 4. 10; Loeb 7: 325) remarks in connection with the hunting of elephants, that "since the elephant is unable to arise, because its legs have only a continuous and unbending bone, they [the hunters] leap down from the trees and cut the animal to pieces." And Varthema (*Travels*, 127) says that "many say that the elephant has no joints, and I say that it is true that they have not the joints as high as other animals, but they have them low."

[137] "incessus."

[138] "moventur."

intercepts a space which is that much greater the further the top part is separated from the knee.

The feet are rounded and divided into five toes, but the division is hard to see. They are flat and entirely unprotected, so that the Romans devised the plan of cutting their feet with axes;[139] they are wide, like the leaden circles[140] we use for feeding. The male has a very large penis, &705 which reaches almost to the ground, though some people deny this. The females have just two breasts, and such small ones that they lie hid under their armpits. The tail is in proportion to a pig's, but almost without any hair, and rather long, so much so that its end is barely a palm's width[141] from the ground. The skin has indeed a very hard outer layer, and is similarly without hairs; it is extremely uncommon for one or two to be collected from here or there.[142] The whole skin is visibly creased.[143] The elephant is hairy on the upper part of its back (which also rises in some manner into a hump adjoining its kidneys), and on its ears, which are very large, and virtually two palms across, and not shaped like ears but like squares. In these two places the hair is plentiful and as it is in the rest of the animals.

The colour of the whole body is uniform—dusky with a mix of ashen, so that one cannot be distinguished from another. Neck short. Head hardly separated from the neck. Eyes very small, but nevertheless it has sharp sight. The trunk extends outward from the top of its forehead, and is not linked to the head like the nose in other animals, but separate, extending right down to the ground, so that its length is almost as great as the animal's height. People call it the proboscis, and some call it the promuscis,[144] and most people the hand. As I said, no one doubts that it is in place of nostrils, after being divided like the nostrils, and the elephant breathes and catches odours with it. Its bottom is like a pig's nose—in colour, roundness, division. But a trunk's substance differs greatly from that of a nose: its use is manifold; it is all fibrous and leathery, so much so that it shortens and lengthens it as it pleases; sometimes it &706 makes it so short that it measures hardly a cubit,[145] and then it is very wide, and sometimes it extends it so that it is narrow and reaches the ground, barely thicker than a human arm. Yet it is of softer substance than the rest of the skin, and so the Romans used to set

[139] At the battle of Thapsus [46 BC] Julius Caesar commanded legionaries to strike at the elephants' legs. W. Gowers, "African Elephants in Warfare," *African Affairs*, 46 (1947): 42–9.

[140] "orbes plumbei."

[141] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

[142] "hincinde"—appears again at 707 (1560) and is equivalent to the classical "hinc et inde," i.e. "on each side."

[143] "cancellatus" in Pliny, *Nat. Hist.* 8. 30.

[144] *L&S* regards this word as "a corrupt form for proboscis."

[145] See n. in Book I to 26 (1560).

about cutting it off.[146] The elephant moves it round on every side, and with enormous speed; if it wishes, it drinks with it, and picks up food with it and puts it in its mouth; it does not actually eat with its trunk, but with its mouth, but cannot eat or drink without its trunk. Its mouth lies hidden below its head, like a pig's mouth, but it totally lacks both the upper and the lower teeth, and has bare gums, and no teeth other than the molars with which it eats, and those two very long ones that protrude on each side, originating from the upper jaw, and running down towards the ground, and with the trunk between them. They run down in such a way that the concavity of the trunk is in front; the one that looks back on the animal is bulging. Consequently its gaze looks upward, so that if it raises its head, it can easily lift on the curve of its tusks a beam of wood, or a man lying crosswise. Furthermore, the trunk has such strength that with one or a second blow, by winding their trunk round them, they lay low trees which twenty men have not been able to overturn. We have seen one pressing with its head on the tree it wished to lay low,[147] and it is assisted by those protruding tusks. It has a tongue so small as to be barely visible. It emits two sorts of voice: a harsh one from its trunk, like a trumpet call, and one from its mouth like a man talking and breathing at the same time, so that &707 Aristotle calls it "panting."[148] It is evident that this is suited for the expression of emotions, and especially of commiseration; hence it is not surprising that horses are not so vastly afraid of the animal as they are of both its voices.

In warfare, the Indians used to tie a sword two [528]cubits long to the bottom of the trunk, and with that it would kill its enemies. It normally recognises from the mahout's voice alone his warnings on whom it ought to strike and whom it should spare. And there is such strength in its body that two of them harnessed together can pull a very large laden boat onto land. In the past, and now too, the Indians often use two iron chains tied round under the belly to attach two pack saddles,[149] one on each side, and put a wooden castle[150] on top of them, in which a team of six men (and sometimes up to fourteen) stand upright, fighting with every sort of weapon.

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[146] For an account of such an episode in a battle between Caesar and Scipio, see H.H. Scullard, *The Elephant in the Greek and Roman World* (London: Thames & Hudson, 1974), 197.

[147] The text reads with puzzling syntax, "Vidimus nos capite illum quae cupit evertere prementem" but I have translated "Vidimus nos capite illam quam cupit evertere prementem."

[148] "Spirabundus"—πνευματῶδες; "If an elephant utters its voice without using its trunk but its mouth merely, it makes a wind-like sound, similar to that which a man makes when sighing and groaning. If it uses its trunk, the noise is like a trumpet which has become raucous" (Aristotle, *Hist. animal.* 4. 9; 536b20–23; Loeb 2: 83).

[149] "clitellae."

[150] Known as a "howdah" (from the Arabic "haudaj").

But nowadays, with the development of artillery, this sort of fighting has lost its value, especially because elephants are afraid of fire, and so the Indians regularly carry torches against them, which frighten them so much that they do far more harm to their own side by taking flight than they do to the enemy by fighting. The females are more hot-tempered and savage, and sturdier than the males, though smaller of body. And—remarkably, since they mature so slowly—they carry a fetus in the womb from the twelfth year (if they start very early) or from the fifteenth (if they start very late); they carry it for all of two years. Similarly, the male starts sexual activity in his fifth year, and really does copulate, and does not return to it except each three years; he has no inclination to enter again a female &708 he has left pregnant.

At birth, the young elephant is the size of a three-month-old calf, and when he walks, he progresses little by little, so much so that he looks like a trained mule or Asturian horse.[151] When larger, they move so smoothly that those who are unaccustomed to riding on them, or who are conveyed in the wooden castles, are overtaken by nausea like people on sea voyages, the animal's body is so large. Even when they are walking gently, a man in a hurry can hardly catch them. They take a great deal of food and drink—an incredible amount. In colder regions they are fed on cooked grain and honey, so as to be able to resist the onslaught of the climate; but in their own countries, they feed on herbs and branches and fruit, which is why they knock down trees. They live in marshy and muddy places, and hot regions. They are eager for glory, and what they learn by day, they generally brood on overnight.[152] They are said to produce the voice of boars, so as to be frightening to horses. But horses used to appear so fearless of the one we saw here, that mules (otherwise very timid) would spontanously approach it; so I think that the account of it in battle and of its voice needs to be interpreted as about angry elephants.

Its trunk has such dexterity that it can even pick up a stick[153]—hence the phrase of Augustus, "like someone about to present a stick to an elephant."[154] It constricts it at the bottom as it pleases, and stretches out some parts, contracts others, so that a human being picking up something with his fingers does no better. The most valuable feature in them is those tusks which protrude, and the penis (among the &709 Indians too) selling for a very high price, for no purpose I know of except sex,[155] and consequently much sought after by kings. And the

[151] "Asturco."

[152] This is reported by Pliny (*Nat. Hist.* 8. 3).

[153] "stipes."

[154] Suetonius (*Divus Augustus,* 53. 2) reports that Augustus sought informality, and to avoid undue reverence in his subjects, with a jest he overwhelmed a suitor who was hesitantly holding out a booklet to him "as if offering an elephant a stick" ("ut quendam ioco corripuerit, quod sic sibi libellum porrigere dubitaret, quasi elephanto stipem").

[155] "ob Venerem."

tusks, because the best ivory consists of them; it is made from all the bones of elephants, but the high quality from the tusks, the cheapest from the bones, the medium quality from the molar teeth. All ivory is steadfast,[156] solid, and shiny white, so that nothing is better for combs. Its distinction is so great that it ranks with the gems and with gold, although a good supply should make it cheaper. It is preserved with oil or water, or else it is dried; on drying, first of all it loses its sheen, then it is eroded, finally it even cracks. So it is protected from damage by the air with the vapour of oil or water. The young ones have whiter and softer teeth, as is the case with every kind of animal; the old ones have larger, harder, drier, darker ones; the best for every role are in adults.

It is unclear whether these tusks are replaced; but if they are, a complete replacement must be done only once. This gave rise to a dispute between Pausanias and Philostratus: Pausanias maintained they were horns,[157] Philostratus that they were teeth—a pretty dispute indeed, but after the Greek fashion (and especially the fashion of their orators), of no use. Juba and Pausanias say they are horns. Juba speaks first, that horns are never replaced as they are in oxen and goats, but teeth are replaced. The tusks of elephants are not replaced—so they are not teeth, but rather are horns. Pausanias, from the contrary assumption, comes to the same conclusion; what he says is that horns are replaced, as in deer, but the larger teeth never are—those prominent ones of wild boars are not replaced. But the tusks of elephants are replaced—so the &710 tusks of elephants are not teeth, but rather horns.

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156 "tenax."

157 Pausanias, *Description of Greece,* 5. 12. 1–3; Loeb 2: 445–46: "Those who think that the projections from the mouth of an elephant are not horns but teeth of the animal should consider both the elk, a beast of the Celtic land, and also the Aethiopian bull. Male elks have horns on their brows, but the female does not grow them at all. Ethiopian bulls grow their horns on their noses. Who therefore would be greatly surprised at horns growing out of an animal's mouth? They may also correct their error from the following considerations. Horns drop off animals each year and grow again; the deer and the antelope undergo this experience, and so likewise does the elephant. But a tooth will never be found to grow again, at least after the animal is full-grown. So if the projections through the mouth were teeth and not horns, how could they grow up again? Again, a tooth refuses to yield to fire; but fire turns the horns of oxen and elephants from round to flat, and also into other shapes. However, the hippopotamus and the boar have tusks growing out of the lower jaw, but we do not see horns growing out of jaws.

So be assured that an elephant's horns descend through the temples from above, and so bend outwards. My statement is not hearsay; I once saw an elephant's skull in the sanctuary of Artemis in Campania." Pliny (*Nat. Hist.* 8. 7) says that Juba called them horns but Herodotus called them teeth. I cannot trace a record of any dispute between Pausanias and Philostratus on this matter; the former was born about 115 A.D. and the latter about 170.

Further, teeth originate from the jaws, horns from the temples; but the tusks of elephants originate from the temples, not from the jaws, and Pausanias says he saw this in the skull of an elephant. Then the teeth which are known as thunderbolts[158] in the wild boar originate from the lower jaw. But in the elephant it is obvious that if in fact they do originate from a jaw, it is from the upper one. The elephant, too, is in the habit of sharpening them, as a bull sharpens his horns, which is unusual in the case of teeth. Finally, the tusks of elephants are softened and bent by fire, a property of horns; teeth are rather burnt up by fire than softened.

Iuba,[159] and Pausanias after him, used these five arguments to show that the tusks of the elephant should not correctly be called teeth, but rather horns. We have two stronger arguments to add. The first is that the tusks of elephants are smooth, and precisely rounded, and lack an edge, which is appropriate for horns; all teeth have a pointed tip, as those of the boar and of dogs and of all the others. Again, as already mentioned, the elephant lacks teeth in the front part, not just of the upper jaw, but of the lower jaw too, which is the property of horned animals only. So these are the horns of the elephant.

Philostratus presents three arguments to show that these are teeth, not horns. The first is that on horns rings grow at the base in relation to the number of years, as occurs in oxen and goats; not so on teeth, but they are &711 smooth all round, and nothing except size is added by the number of years. But the tusks of elephants are like that—smooth, and without rings. They [529]are solid all round, and have no empty portion except a very tiny foramen, which is appropriate for teeth.[160] But horns are empty inside, as may be seen in oxen. Again, there is no animal endowed with horns except those that have hooves, and cloven ones too, such as deer, roe deer, oxen, she-goats; but the elephant has no hoof on his feet, but toes, and its feet are not cloven, but divided into five parts. The Greeks[161] quibble like this, in the utter insensitivity[162] of shallowness and inexperience—the first argument of those who say they are horns is so ludicrous that opposites assume hypotheses for coming to the same conclusion.[163] One of these

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[158] Ovid, *Metamorphoses*, 10. 550: "Fulmen habent acres in aduncis dentibus apri,"—"The high-spirited boars have a thunderbolt in their hooked teeth."

[159] Juba II, king of Mauretania, was led in Caesar's triumph in 46 B.C. and died ca. A.D. 23. He wrote many books in Greek, all now lost, but Pliny used them, citing them some 20 or more times, as did Plutarch (*OCD*).

[160] This is untrue; the tusks of the male African elephant have a cavity extending into slightly more than half the tusk length, and the female's extend into about one third of the tusk length (T. R. Layser and I. O. Buss, "Observations on morphological characteristics of elephant tusks," *Mammalia* 49 [1985]: 407–14).

[161] Juba and Pausanias.

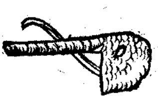
[162] "stupor."

[163] "ut opposita supposita assumant ad idem concludendum."

people (Juba) wishes the tusks of elephants never to be replaced, but Pausanias wishes them to be replaced; yet if one or the other is accepted, no conclusion can be drawn, since there are some tusks and some horns that do get replaced, and some never do—for instance, deer do replace their horns, oxen do not. Among the boar's teeth, the "thunderbolts" are not replaced, nor are the anterior molars.

What Philostratus says, that the tusks of elephants earn the name of teeth because they are solid, not hollow like horns, suggests enormous insensitivity—firstly because not all horns are hollow, indeed most are rather solid, like those of she-goats and deer; those of oxen and buffaloes[164] are hollow. Next, a more important point, and one suggesting that he was &712 careless and dozing[165] while writing that little story, and had never even seen an elephant's tusk, of which there has always been a very large supply: he dared to say that the tusks of elephants are not hollow inside, when they obviously are, just like the "thunderbolts" of boars in the whole of the part that is inserted into the temple. But all teeth are not solid, as he presupposes, since (as I said) the tusks of boars, which protrude in the whole part where they are linked to the jaw, are hollow and empty. Such stupidity on their part makes me ashamed—that virtually pointless question, and that it was to be answered from the substance of the thing; the issue could be resolved by a couple of words. It is in fact accepted that there are teeth; their substance is matt white, with little translucency, and not readily capable of bending; if it is forced, it breaks. There you have the proper and very serviceable solution of the question. However, it is shaped by fire—I grant this, and we will explain that even bones are shaped by fire, but not so readily as horns. The better

Fœmina,



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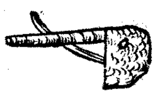

point to raise is why an elephant is endowed with such a form, and particularly the point that the male's tusks face completely backward with their concavity, but the female's are humped, as you see in the figure. We have not seen this ourselves in the case of the female, but we trust Aristotle's consistent statement. So we must enquire carefully into this; it cannot be believed that &713 nature did this casually, but under great necessity, and with greater wisdom. This cannot occur without a purpose in sight. As we will explain later on, the purpose is that nature aims at the ideal perfection in all respects; that is, to be made like the gods, so to speak. They are especially outstanding in length of life, blessedness, wisdom, and peace of mind. Nature's effort was to devise an animal like this, so far as it could. For this animal to be long-lived was a feature in great need of the principles of life; they are heat and moistness. Similarly in respect of size, to make it not only safe from injury by all the other animals, but also resistant to the violence of the air. No small animal can be very long-lived; if it happens to be of rarefied parts, it is eroded by the

[164] "bubali."

[165] "oscitantem."

constant pulsation of the surrounding air, and gets dispersed. But if it is to be of thick substance, it perishes quickly of itself, as oxen do.

Size too was appropriate for safety, just as goodness of temperament was required for wisdom along with length of life and good repute.[166] But to secure heat and moistness in plenty, it should be born in hot regions and live in marshy places; in consequence it is found only in India and Africa—these are the hottest regions. And Indians greatly outdo Africans in strength and body mass, because India is rich in waters, but Africa is drier. It needs to feed on plants and fruits and herbs, for otherwise the animal could not be of good repute[167]—all the animals that feed on &714 flesh are short-tempered, deceitful, cruel, and proud. A further point was that for such a bulk a great deal of food would be required, so that the elephant would be compelled either to be forever hungry, or to destroy all the other animals. It was also necessary for it to be in continuous motion in pursuit of wild animals, which would have been troublesome for so large a bulk. But since herbage provides little nutrition, it would make for a short life, as Hippocrates[168] says; hence it was appropriate for the elephant to feed on tree trunks and fruit.

But a great deal of earth is mixed with these, and sometimes pebbles too, so that it was essential for its body not to be upset by eating such things, or it would be forever unwell. But fruit and tree branches are very often taller than nature could make an animal big enough to reach them—so it armed it with a hard head and trunk, and with tusks, so as to push trees down.

And the trunk's length helps in the plucking of fruit and branches, to avoid its being forced to push down all the trees, which would be a hard task for it, and damaging not only to itself but to others, through the removal of food for the future. And to make it safe against lions, nature made these tusks— horns were unsuitable for two reasons: because to use them they are compelled to flex their necks, and because they do not see their enemy so well. But flexing of the neck demands length of neck; so for the elephant to be very strong, a short neck was required, and one minimally flexible. This is why lions too bend their neck rarely or very little. And in human beings too this [530]is a sign of strength and vigour, &715 if it comes from nature. So before nature shaped these tusks, it did not implant them in the lower jaw, nor in the upper one either, but in the temples, so that they were very strong and useful. For the lower jaw alone moves for eating, the upper teeth never do—though many people do not observe this even in themselves. So if the tusks had been implanted in the lower jaw, it is so small that they could possess no strength, and in a great effort they would create the danger of dislocation, and would get remarkably weary during eating, and slow up the elephant.

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[166] "probitas."

[167] "probus."

[168] Source not traced.

But since matter was needed for the tusks so as to shape such large ones, nature removed all the front teeth, both upper and lower, to make tusks out of them, but in combination with the short neck, the tusks created an obstacle to the mouth reaching the ground. And as the elephant had no front teeth, it could not pick up food from the ground, nor take drink from springs. Nature came to the rescue in all these problems with that long empty trunk, that grasps everything like a hand, with its very tough skin and its fibres, ligaments, and cartilages. And Nature therefore arranged that it could be contracted or extended at will, or rotated in any direction; this is the way in which it and the tail squash flies and hornets.

But when there is too great a quantity of these pests there for the tail or trunk to be able to drive them off all together, actually because of some points that neither the tail nor the trunk can conveniently reach, nature deals with these problems in two ways. Firstly by the &716 grid-marked skin, where the elephant squashed the pests trapped by it. Secondly, the fact that the skin was very hard and thick was not only very useful but also essential, both to repel the onslaughts of the air and to provide security against lions and other rather large beasts.

The result is that it turned out inconvenient to grow hair, the skin being so large and hard; when moved into the skin, the matter for hair makes it harder, and consequently made hairs less necessary; if they had been present, they would have created considerable difficulty when the elephant moved about in water or marshes. Thus with one shake of its back, the whole elephant glints, and very soon gets dry. But since the tongue exists on account of the teeth,[169] and the elephant has no front teeth, a small tongue concealed within is required, since its role is to care for the molar teeth. If it had been large as well, it would have obstructed the presenting of food right to the molar teeth by the trunk.

But since food required excellent chewing for length of life, and could not be split up by front teeth which are lacking, molars were constructed so sturdy and convenient that (as Aristotle confirms) all the food is instantly ground into flour.[170] It also ensured that the offspring would be carried in the womb for a long period, on account of the length of its life—and also, the length of its life was a reason, so that although the female gestates for two years, she can still produce many offspring; in fact, no animal which is carried for only a short time in its mother's womb can have a long life.

The small eyes, incapable of being recessed, make it &717 safer against blows. They could not be recessed, because lying laterally they would not see what was going on in front; they had to lie laterally to avoid damage because of

[169] I have not traced an Aristotelian source of this statement.

[170] The meaning is clear although the syntax is not: "molares . . . fabricavit, ut . . . cibum . . . redigat in farinam." "The elephant has four teeth on either side, which it uses to masticate its food, grinding it like coarse barley meal . . ." (Aristotle, *Hist. animal.* 2. 4; 501b30–32; Loeb 1: 101).

the violently working teeth and the nearby trunk; in that way the animal would be rendered blind before old age, especially as it was on the way to a long life. And since it was compelled to form a large head, for strength and for the tusks, it makes an unsightly one, so to speak, and one devoid of roundness; any kind of addition made to its head for ornamental purposes would have hugely increased its size; this is why elephants have a very ugly head.

We have spoken about its length of life and its security, which are also combined with enormous strength. Its sagacity proceeds from its temperament, and is augmented and reinforced by its length of life. Hence the old ones are more sagacious, and those that are born from them. And no short-lived animal can be very sagacious. Hence the most sagacious animals are the camel, the elephant, and man. And these outdo all the others in length of life. I mean the kind of sagacity which is the fruit of circumstances, not the inborn kind, which even insects possess. It is from sagacity that uprightness[171] proceeds; we have in fact shown this in our books *De Sapientia*.[172] And it is from the same causes that length of life and actual sagacity proceed. The purpose of uprightness and sagacity is for the animal to be fortunate, and at the same time living in a herd,[173] a feature which also contributes much to its security—all the solitary animals are most unfortunate; all good fortune, which is beyond reckoning, is obtained through the &718 custom by which we protect and cherish our dear ones, and they look after us in return.

And so it is already clear why nature has created the elephant as at once the largest, strongest, longest-lived, most sagacious, tamest, most secure, and most fortunate of all beasts, since in detail five of these items were of the utmost perfection, in imitation of that supreme perfection which is in God; the other two are essential for these five. From this it is clear that man is of another kind, separate from the nature of all the beasts, and something immortal; nature has in fact granted the elephant the ultimate perfection that could be created from mortal matter.

This animal appears to have some likeness to the pig—the tail, the trunk, the skin, the temperament and way of life; when provoked, it is savage, but gentle at other times; and pigs do themselves go about in herds, and are fond of marshy places, and have small eyes. But pigs have a cloven hoof, while elephants have five toes which are not divided, but only slightly separate. And elephants lack front teeth—pigs have them, and tusks too in the lower jaw, not in the upper one nor in the temples. This animal pursues vast hostilities with the Rhinoceros—this is the Indian bull. It has a body nearly of a size with the elephant, shorter legs, a colour like boxwood, and is armed all over by nature with a kind

171 "probitas."

172 *De Sapientia*, originally published in 1544 (Maclean, *De libris propriis*, M47).

173 "gregale."

of shield made of scales.[174] In accordance with the [531]meaning of its name,[175] the male bears on the tip of its nose a horn a little larger than a palm[176] in length, &719 very hard, very tough, straight and very sharp, but bent towards the front, and it sharpens it for a fight. And some of them have another small horn as well on their back. The story goes that in the year 1513 A.D. one was brought to the King of Portugal on the first day of May, and two years later the King matched it with an elephant as an entertainment at Lisbon, and the rhinoceros won. Nature was so concerned that nothing is to be entirely safe from harm; the rhinoceros is the only thing to disturb an elephant (some people say that a snake can too). But being in the herd makes an elephant safe from both, and it is not subject to danger unless some cause separates it from its herd. Pausanias saw a rhinoceros, and Pliny was aware of it,[177] but not Aristotle. It is agreed that it is quite different from the Monoceros, sharing with it only the resemblance of name. The Monoceros is a rare animal, the size of a horse, with hair very like a weasel, the head of a deer, on which a single horn grows, three cubits in length, in the middle of its forehead and straight, wide at the bottom, narrowing to a point.[178] Neck short, crest very scanty, and inclining to one side only. Legs thin like a roe deer's, the outer surface of the rear ones shaggy with much hair, hooves cloven. In summary, if you think of the nature of a deer, this creature is not unlike, apart from its horn. It is very wild. It is born in Ethiopia amid uninhabited places and barren earth and snakes, and its horn is believed to counteract poisons extraordinarily. I think this is the animal which Aristotle calls the oryx.[179]

&720 But an animal is born under the North Pole in a totally contrary quality of air; it is like a deer, with its front legs rather long, and a fleshy appendage, though a short one, and if its hooves are hung round someone's neck, it is thought

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[174] "testa."

[175] "rhinoceros" means "nose horn" in Greek.

[176] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

[177] Pliny (*Nat. Hist.*) mentions the rhinoceros six times.

[178] The Latin equivalent of "Monoceros" is "Unicorn."

[179] This sentence first appears in 1560. Aristotle, *Hist. animal.* 2. 1; 499b19; Loeb 1: 89: "The oryx has a single horn and cloven hooves." And at *Partes Animal.* 3. 2; 633a24; Loeb 221: "There are, however, some animals that have one horn only, e.g. the oryx (whose hoof is cloven) and the 'Indian ass' (whose hoof is solid)." So Aristotle apparently believed that the oryx resembled the "unicorn," rather than that it had two unbranched horns. Pliny too believed in the unicorn: "a very fierce animal called the monoceros, which has the head of the stag, the feet of the elephant, and the tail of the boar, while the rest of the body is like that of the horse; it makes a deep lowing noise, and has a single black horn, which projects from the middle of its forehead, two cubits in length" (Pliny, *Nat. Hist.* 8. 31.76). See Lavers, *Natural History of Unicorns.*

to cure epilepsy[180] as well as anything can.[181] While the animal is being afflicted with this disease (it is afflicted with epilepsy), it cannot be roused until it puts the hoof of its back leg into its ear—then it is roused at once from the disease. It is timid and incredibly feeble, and dies from any tiny wound. It actually has a very cold heart, and a brain not only cold but overflowing with phlegm. It has horns possessing a special form, and like those of almost no other animal: thick at the bottom, and where they rise up they are of more than a palm's width.[182] Some call it the wild ass,[183] because it has long ears,[184] also sometimes a solid hoof, even if rarely; it is certainly very speedy, so as to cover two hundred miles in a period of twenty four hours. It exists without food and drink for this whole period, "zethicum mansuescit avidum."[185] It is plentiful among the Dacians[186] and neighbouring regions, and in common speech they call it the Large[187] animal. But it is quite different from the elk; the elk,[188] as Caesar described it,[189] is like a he-goat, with a blotchy skin, and has legs without a joint. But we can see its joints, and a skin like a stag. However, we will discuss the elk later.

Ethiopia produces another animal, with a front part like a fox, the tail and back part of a long-tailed monkey,[190] the front &721 legs human, the ears of a bat, and it has a "money-bag"[191] under its belly, in which it carries its young in every direction, and does not release them except when it wishes to suckle them.

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180 "comitiales."

181 1550 states it is wrongly alleged to have no knees, and the rest of this paragraph appears first in 1554.

182 On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

183 "onager."

184 Hard to explain, since the word "onager" is simply derived from the Greek for "wild ass" (Isidore, *Etymologies*, 12. 1. 39).

185 I cannot translate this; "zethicum" is not recognised by the usual dictionaries, although of course it suggests beer (ζῦθος) to some extent. These two preceding sentences first appear in 1560.

186 North of the Danube.

187 "Magnus."

188 Cardano uses "alces" as the nominative case here, but the classical form is "alce" (*OLD*); Caesar (*Gal*. 6. 27. 1) uses "alces" anomalously as the nominative plural.

189 Caesar, *Gal*. 6. 27. 1; see n. 94 above.

190 "cercopithecus."

191 "crumena."

And the West Indies produce the Chiurca,[192] of the weasel family, which carries its sons with it in the same fashion.[193]

In this same Ethiopia there is another kind of ox, with darkish hair, but the horns of a stag. However, if I want to record every kind of ox, a more verbose account will be required than would suit this book; recently the Queen of Bohemia took with her two Spanish oxen, of which one had horns two cubits long. European bison[194] exist from the same kind, of which Aristotle gives an account.[195] There are black oxen in Italy, with horns black and very welcome for works of art; the inhabitants call them buffaloes; they are not found in the whole of Italy, but only beyond the Apennines. They are so wild that they can only be led round by an iron ring inserted in their nostrils;[196] they are aroused by red and by a mixed colour, and strike down human beings—they are so sturdy that they can pull the weight of two oxen. They have horns that are more flexible and suitable for workmanship, with a dark colour being especially helpful for oxen,[197] they have little hair and a short tail. And when they are aged, their flesh can hardly be eaten; they seem so different from the general kind of oxen.

But why do I spend so much time on them?—it is better to know the differences between all the horned animals, and their usefulness and nature, with the principle being sought more profoundly, as it should be. It was shown previously that the animals that were herb-feeders have blunt teeth, not very sharp ones, and that is the reason (beside their &722 nature, which recoils from eating flesh) that they are not adapted for the defence that can be made with teeth. This is why they are armed partly with horns and partly with stouter claws. But the claws have already been dealt with; what remains, then, is for us to show that of the animals that possess horns, some are provided with solid ones and some with hollow ones. All those that are armed with hollow ones have two, as oxen do;

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[192] "Some count the Chiurca a ferret . . . Scaliger writes that the Chiurca hath a ferrets face, and bulk, a foxes head, lives under ground, is very fruitfull, bringing at birth twelve at once. The tayl small, and almost bald; itself is black-haired, carrying her young under her belly in a bag" (J. Jonstonus, *Description of the Nature of Four-footed Beasts* [Amsterdam, 1678], chap. X, art. 1).

[193] 1550 now discusses unicorn cows in Ethiopia, which 1554 and 1560 do not, and the subsequent material up to the discussion of the lion at 732 (1560) appears first in 1554.

[194] "Bomasi," which is a mis-spelling for "bonasus," the European bison, now known precisely as *Bison bonasus*. Pliny (*Nat. Hist.* 8. 40; Loeb 3: 33) says that when in flight, it "emits a trail of dung that sometimes covers a distance of as much as three furlongs, contact with which scorches pursuers like a sort of fire." This stems from Aristotle (*Hist. animal.* 8 (9); 630b8–10; Loeb 11: 391).

[195] In *Hist. animal.* 8 (9). 45; 630a18–b18; Loeb 11: 387–91.

[196] The rest of this sentence together with the next one appear first in 1560.

[197] Syntax unclear: "et ad opera accommodata cornua, habent bobus nigro praesertim adiuvante colore:"

but those armed with solid ones either have one, as the Monoceros and Rhinoceros do, or two, as she-goats and chamois[198] do, or more, like stags and those of that kind (such as roe deer); these have branching horns, instead of having more numerous ones.

This needed explaining first; when nature had planned to generate additional horns, if they were scattered all over the whole head, firstly they would all except two be useless for defence; secondly, they would not be close to the ears—ears are dry by nature, but the other senses would encounter obstruction from the matter of the horns. Hence no animal possesses more horns scattered over its whole head, except some wethers,[199] animals already mentioned.[200] However, it is said that reindeer have three horns, and that the horned asp[201] has seven (Pliny[202] says four pairs). There are certainly four on snails, but two are very long, two are short, and all can contract. And there are more on two particular kinds of insect; but they were given to the snails for feeling their way, and to the asp for creating a [532]deception; while the rest of the body lies hidden in the sand, the horns stick out like grass sprouts, and so are not for defence and combat, but (as I said) for deception.

&723 The same function[203] applies to the horns in what are called insects, or any other one except combat, apart from the case of some kinds of beetle; it is established in these, and others if any that fight with horns—beetles have mobile horns, and those that serve as weapons are just two.[204] It is also said that there are some animals provided with more and various kinds of horns, which should be reckoned as produced by various kinds of animal. But to revert to the earlier classification:[205] the horns on stags are branched, and so are those on Scythian reindeer of the same kind. Roe deer too have branched ones, and as I said, these take the place of multiple horns. So whatever has branched horns virtually has many horns; this is in fact nature's intention. And these same creatures of necessity have solid hard ones—and are timid, and stupid, and fleet of foot.

So this needs explanation. In every explanation, we need to adopt three assumptions.[206] The first is, that nature has filled up all the limbs of the classification,[207] so far as was possible, otherwise it would have been foolish.

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198 "dama": general name for deer, but especially chamois.

199 i.e. castrated male sheep.

200 At 686 (1560).

201 "cerastes," also known as the horned sand viper.

202 Pliny, *Nat.Hist.* 8. 85; Loeb 3: 63.

203 "ratio."

204 Two sentences present here in 1554 but not in 1560 discuss whether reindeer are one species or more.

205 "divisio."

206 "supposita."

207 "divisio."

For when the order had been given to embellish the world, nature could not do this better than by fashioning every kind of animal included in the first classification,[208] just as if arranging a garden and embellishing it with flowers of every kind. The second assumption, the nature of the animals, being not secure enough to stand up, is necessarily lacking, and hence no variety[209] of such animals can survive. So in all varieties there is enough to provide for their protection. &724 The third assumption is that animals have been generated for their own sake and for the purpose[210] of general embellishment, not for that of other animals.

On these three assumptions, when it had been determined to make animals provided with horns like trees, and to complete the first limb of the classification, it was inevitable firstly that there were no more than two horns, but branched ones; branched ones hard and solid to prevent breakage; since they are not alive (they would have been provided with veins and nerves), and were so soft (soft weapons are no good for combat), they were unable to bend — hence they had to be hard — any soft thing is unsuited for violent use unless it is flexible — a flexible thing is moist and alive, as tree branches are. It follows that timber, not being alive, is either dry, or (if hard) is flexible. So horns have to be both hard and dry and solid; from a hollow thing nothing solid can originate, nor a hollow thing with sturdiness. So branched horns are solid and dry and hard.

Hence, as matter of this kind pours from the brain and is generated from blood, horns will have blood and a dry brain, and be rich in much earthy element. But we have shown that everything like this is not fully developed,[211] so they are all stupid and timid; these are the consequences[212] of plentiful black bile,[213] whether in the brain or in the blood. Being foolish and timid, they need to be fleet of foot to survive; as we said, those that cannot be speedy do not establish a variety.[214] They become speedy by practice and through fear.

Everything armed with only two horns, and those horns &725 solid ones, is both foolish and timid, and has horns that are hard and dry. But those that are not very timid or foolish are fleet of foot, for the reasons mentioned. There are many of this kind: roe deer, chamois, goats,[215] or the ashy-coloured ibex that live on mountain ridges, which get blinded unless they live in very cold places.[216]

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208 As described in the Bible (Genesis 1: 24–25).

209 "species."

210 "causa."

211 "crudus."

212 "affectus."

213 "melancholia."

214 "species."

215 "capricorni," but this word normally means "having a goat's horns" and refers to the zodiacal sign.

216 Pliny mentions the ibex (*Nat. Hist.* 8. 214) but not the blinding.

Their horns sometimes have eighteen internodes, each one indicating a year. The size of the horns at times exceeds a weight of fourteen pounds, so that they become appreciated as drinking vessels. We saw them at Sicini and in the villa of St Maurice,[217] or among the Sedusii[218] and the Antvertes;[219] they are very dark. The chamois[220] in Germany, light in weight and like goats, have wider horns, since they are dry and weak animals, and are made thinner by the cold; wide means weak, just as rounded means sturdy. So these animals live amid the boulders, because they are not weighed down by the horns on their head, nor do they lack anything towards lightness and robustness, being very dry. The she-goats are more tame than those wearing branching horns, so much so that I have seen a trained she-goat ascend seven wooden pipes[221] placed one on top of another, until it climbed up to the ceilings. Ferrando (once upon a time a Turk, now turned Christian) used to set up a wooden pipe no more than the width of a fist, and the goat used to put on it first one foot, then the other front foot, and afterwards the back feet in the same order; when it had climbed up, Ferrando used to set up another pipe, placing it under a foot; then little by little &726 it put on it one of the front feet, and the back feet in the same way, till little by little the one pipe stood upon the other pipe. While he held the pipes together right to the seventh, the she-goat used to make its way up in the same fashion, till it was standing almost with its back under the ceilings. And so this animal was not found so stubborn as to be entirely untrainable. In addition, the same goat had learnt to make its way across tiles arranged in order, imitating its master, who was a tightrope walker. By a natural property, she-goats detest human saliva, and eat nothing that has previously been tasted by man; the nature of lizards is contrary, and they eagerly lick it.

But as among those animals that have solid horns, the she-goat is more docile, so is the reindeer among those that have more, and branching ones. People tame those that have been caught in Lapland;[222] they are born there, and harnessed to chariots; and used instead of horses, they cover more than 150 miles a day;[223] they are of sturdier body but have slenderer horns than stags. And perhaps they only have two horns, in accord with nature—but more by chance, as is

[217] There are several places of this name and it is unclear which Cardano means.

[218] They were a German tribe among those against which Julius Caesar made war (*Gallic War* 1. 51) but their location in Cardano's time is not evident.

[219] Probably the inhabitants of Antwerp, in Belgium.

[220] "damae."

[221] "tubulos."

[222] "Laponia"—more conventionally "Lapponia."

[223] On the length of a mile, see n. at 34 (1560) in Book I. "150 millia passuum" is about 224 km. At http://www.ansi.okstate.edu/breeds/horses/kabarda/ (accessed on 23 Feb. 2008) a modern record is mentioned of a horse covering a distance of 50 km in 1 hour 41 min 25 sec.

said to occur in wethers. Indeed, since they are branched, and supported by more close-packed branches than stags have, it is believed that to possess more ranks of horns is pointless. Or, as in plants which germinate quite generously (such as apple and hazelnut trees) branches and twigs emerge from their foot, which normally originate from shoots. This is the way in which shoots originate from the root of [533]two horns, though they ought to originate from the trunk, and in that way they exhibit the likeness of many ranks.[224] Overall, the reindeer as a rule has three horns: two very long ones at the sides, and one in the middle, a small one; &727 they are all branched. But why comparable ones occur in most animals, but a single one for the oryx, the donkey of India, and Ethiopian bulls, is a point to be settled by dissection; as in all cases there is right and left, it is proper for there to be just twin horns too, so that in plants the principle[225] corresponds to the number of leaves: only pairs, because of the weight.[226] But where the parts of the brain combine into one, it was better for there to be a single horn, not two, to provide strength. So every animal endowed with just one horn has a hard one, solid and large. The common feature in animals possessing more than two horns appears to be that the female has none. Consequently Pliny believed that the matter of teeth does not pass over into horns, since the females, without front teeth in the upper jaw, have no horns.[227] The reason is twofold, drawn evidently from the final cause and the efficient cause: when the mothers carry the fetuses in their womb, they need to be light and nimble, so that very large and branched horns would be a nuisance to them. This kind of animal is also timid, so that the females are extremely so, and thus horns would be of no use to them. There is also a deficiency of heat to be capable of generating the matter for horns, and once generated to expel and extend it; thus horns are to stags what a beard is to human beings, so that they seem made for decoration alone, and neither of them is present in the female sex. This system is also visible in herds: the bulls are horned, the cows are not.

However, anywhere on the mountain ridges of very cold regions the females have horns too, since because of the &728 coldness of the air their natural heat is reinforced. Rams fight with their horns, though in these animals the horns are shadows and shapes of weapons, not real weapons. But you will say: "What makes for their safety, since their horns do not?" Either there is no species of sheep, then, or sheep appear to have been made for humanity, not for themselves. But the sheep has its origin from Sarmatia,[228] where it is called "Suas." There are

[224] The next two sentences appear first in 1560.

[225] "ratio."

[226] Meaning evidently that an unpaired leaf might unbalance the plant.

[227] Pliny (*Nat. Hist.* 11. 128; Loeb 3: 153): "Those who think that the material to form upper teeth is entirely used up in horns are easily refuted by the nature of does, which have no teeth that stags have not also, and nevertheless have no horns."

[228] For Sarmatia see n. in Book II at 200 (1560).

flocks of very swift beasts, wool of an ashy colour, flesh so sweet that the kings of the Parthians and Scythians (both regions now are included under the name of Tartary) do not despise the hunt for them. It is credible that they had their origin on this basis, and were tamed, because they are clad in wool against the cold, like other beasts of other regions with rather costly skins. Why wool is of an ashen colour does not seem a question worth exploring; in fact in cold regions most animals are of a matt white colour, for instance in the rock of Cyllene[229] the blackbirds[230] are entirely matt white, and Pausanias saw shiny white eagles in Sipylus[231] around the marsh of Tantalus.[232] Mount Sipylus is in Asia Minor near greater Phrygia, and Cyllene is in Arcadia. The same author recalls that he saw shiny white boars and bears born in Thrace, and shiny white stags at Rome, and shiny white hares born in Libya. People used to call shiny white eagles "swan-like,"[233] because they were exquisitely white and very like swans. But the reason why shiny white animals develop in cold regions is not obscure: grey hair arises from mould, and mould from disuse,[234] and disuse from feebleness of heat, and &729 feebleness of heat from excessive chilliness of the air, in the skin particularly, which is exposed to the air all the time, and as well holds little heat from within itself. It also comes on sometimes, though rarely, through external heat, with the innate heat breathing out; hence in hot regions like Libya it is not absurd for hares to be matt white. On mountain ridges in Germany the presence of white hares and roe deer and shiny white stags is not only no marvel, but compatible with reason. Pausanias however affirms that he did see shiny white stags at Rome, but does not know the source from which they were imported.[235] At Rome there was a profusion of such items and of others, since they were rulers of the world. A recollection has swum up of the poetry of Titus Calpurnius Siculus[236] in his *Bucolicum*:

> I saw every kind of beast here, snow-white hares, and boars complete with tusks. We saw the mantichoras,[237] and the elk too in the woods that

[229] A mountain in Arcadia in the Peloponnese of Greece

[230] "Cossyphi." This is evidently the Greek κόσσυφος; for full details see D'Arcy Thompson, *Greek Birds*, 174–76.

[231] In western Asia Minor, near Smyrna.

[232] Pausanias, *Description of Greece*, 8. 17. 3.

[233] "cycneas."

[234] "situs."

[235] Pausanias, *Description of Greece*, 8. 17. 4.

[236] Roman poet who flourished about A.D. 50–60. For the scanty details available on his life, see *OCD* under "Calpurnius Siculus."

[237] A mythical creature of Africa or India, possibly based on the tiger. The word may be derived through Greek from a Persian word for "man-eater" (*OLD*) and is spelled "mantichora" by Cardano. Pliny recounts that this alarming Ethiopian beast "has a triple row of teeth, which fit into each other like those of a comb, the face and ears of a man,

> produce it, and bulls, on some of which an ugly bulge protrudes from their shoulderblades as they raise their heads,[238] while others wave hairy crests along their necks, and others have their chin covered by a rough beard, and their dewlaps quiver with bristles.[239] And it has not only been our lot to view monsters of the woods; I have also seen seals, and bears battling with them,[240] and a herd known[241] by the name of horses,[242] but ill-formed, because born in that famous river which irrigates the fields on its bank with its springtime[243] waves.

There is nothing fabulous described here, although a poet is at work; it has a marvellous and barely credible shape; we are aware that the account of the Nilotic horses is well known. They are also said to be &730 marine. And we will explain how their teeth are like ivory ones; in the front part they resemble horses, in the back part they end up as fish. We will describe seals[244] below. There are Paeonian bulls with shaggy crests, in which the hair is shaggy over the whole body, but especially on the chest and the mandible; Pausanias reports that he saw this. And those on whose chins there is a prominent beard are called aurochs.[245] These are sturdy German bulls, and under their chin there lies a beard as on he-goats. Regions in fact possess some of their own, for instance Sardinia has the "muflum,"[246] very like a stag—indeed it is one, but with the horns of a ram, and we can rightly also call it "subulo."[247] But if the "subulo" and the "muflum"

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and azure eyes, is of the colour of blood, has the body of a lion, and a tail ending in a sting like that of the scorpion," and can imitate human speech (*Nat. Hist.* 8. 75 and 105; Loeb 3: 55 and 79). But unfortunately for this creature, Keene's (*The Eclogues of Calpurnius Siculus and . . . Nemesianus*, ed. C.H. Keene [London: Bell, 1887, repr. Hildesheim: Olms, 1969]) and other recent editions of this passage (Calpurnius Siculus, *Eclogue* 7. 57–63), instead of following older editions such as the Aldine from about 1500 in reading "Manticoram sylvis etiam quibus editur Alcem / Vidimus," read here "hic raram silvis etiam, quibus editur, alcen. / Vidimus"—"here the elk, rare even in the woods that produce it. We have seen . . ."

238 Translating "aut cervice levata" with Verdière, not "ex cervice levata" with 1560. This is the zebu, the humped ox.

239 Probably the European bison (Verdière, 264).

240 Suetonius (*Nero*, 12. 4) mentions Nero staging a sea battle, with beasts swimming around..

241 Translating "dictum" with Verdière, not the "dignum" of 1560.

242 Hippopotamuses in the Nile; as Verdière points out (209), the word "hippopotamus" cannot be fitted into the metre of a hexameter, used here by Calpurnius.

243 Translating "vernantibus" with Verdière, not the "venientibus" of 1560.

244 "vitulus marinus."

245 "uri."

246 This word is evidently the ancestor of French "mouflon," a type of wild sheep.

247 "A stag at the stage when it has unbranched straight pointed horns, a pricket" (*OLD*).

differ,[248] they differ on the basis that the "subulo" has longer and more solid horns, like she-goats: the "muflum" has shorter, twisted horns, and they are hollow from the start, as in the ram. Species are actually mixed up in extraordinary ways, either through [534]coitus (as mentioned already in the case of that remarkable animal),[249] or through the effect of region—as we said, the German bulls have a long prominent beard and a bigger body, the Paeonian ones are hairy, the Libyan ones (called "Lant" in their maternal language) have a shiny white body, black claws,[250] or rather hooves, with impervious skin, and for that reason and because of its beauty, the skin is costly. This animal is speedy, because of its habits and its food.

The colours of snakes also vary with regions: in Ethiopia and Libya the vipers are dark, as indeed are the human beings, as Pausanias testifies;[251] being hairless, their skin gets burnt, as does that of the human beings because of the excessive heat, and so in these regions no more &731 account is taken of the human beings for being dark than of the vipers. They alter with age too, as mice do, which go grey in old age. And not just the animals themselves, but those begotten by them show the traces of extreme old age, as occurs in horses, and in human beings, whose face is wrinkled when they are born from enfeebled parents—when the heart's force is blunted, it contracts the skin, and this points to already weak main organs. Indeed, we have often noticed this. And so the first principle of change is due to the mixing of diverse species, the second one is due to regions, the third is due to age and to generation from parents that are too young, or worn out by old age. The biggest change occurs in regions inclining towards the south or the north, thereafter from east to west, later in marshes or dry places, finally in the diversity of mountains and flat ground. Libya gives rise to many monsters, not just because of the huge heat and dryness, but because of the lack of water, which leads to animals of diverse kind being mingled: for instance, some bulls, which we said are rhinoceroses; others are notable for a hump, as camels are, which this poet remembers. The elk has been mentioned above, and that it is rarely seen; Pausanias gives the cause of this when he says, "It can smell a human being far off, and when it has detected one, it hides in gorges and very deep caves, and it is not permissible to hunt it on its own, but to come upon it by chance, when hunters have enclosed a space of a thousand stadia on a hunt for other wild beasts. He

[248] "Sed si differunt subulo mufloque . . ."—the "muflum" appears now as "muflo," presumably by "attraction" to "subulo," and continues to appear thus in the nominative case.

[249] This is evidently "that animal which we saw at Pavia on the nineteenth of January in the present year," at 682 (1560) above.

[250] "ungues."

[251] Pausanias, *Description of Greece*, 9. 21. 6. But in fact Pausanias refers only to Ethiopian "asps" as being as dark as men.

says it falls between a stag and a camel, because they &732 perhaps have a hump on their back."[252] Or this is different from the one that Caesar described.[253]

The manticore does not have a reliable author, but I regard it as a poetic adjunct. Ctesias[254] (whom Pliny[255] follows) describes it, and it is on his authority that Aristotle[256] remembers it, though not entirely confident in him. But it is extraordinary that it was not seen by so many generations[257] of Romans, nor by Pausanias. They place it in India; but as I said, Libya is in the same region, and so is Ethiopia, in which tigers are as plentiful as wolves with us. The tiger is thought to have a speckled hide. We have seen two of them at Florence, which people said were tigers, though they resembled leopards.[258]

The[259] lion is born in the same places—almost the boldest of the quadrupeds, and its bones are said to emit fire when struck together; they are very hard and solid, and virtually without marrow; long body, tawny colour, keen gaze, long tail which it very often shakes, hair in front not straight, but soft and curly. Skin entirely impenetrable; body shorter at the back, head large, wide gape of mouth. So much strength of neck and teeth that it carries a camel grasped in its mouth; so much courage (or rather, rashness) that it can on its own attack two hundred knights; armed with very large and hard claws; a hoarse roar. Nature has created a wrathful creature, because it is a very brave one; and being of such a hot nature, every second day it languishes with illness and it roars, not all day, but at determined hours—not all lions maybe, but those that are in captivity.

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[252] "There is also a beast called the elk, in form between a deer and a camel, which breeds in the land of the Celts. Of all the beasts we know, it alone cannot be tracked or seen at a distance by man; sometimes, however, when men are out hunting other game they fall in with an elk by luck. Now they say that it smells man even at a great distance, and dashes down into ravines or the deepest caverns. So the hunters surround the plain or mountain in a circuit of at least a thousand stades, and, taking care not to break the circle, they keep on narrowing the area enclosed, and so catch all the beasts inside, the elks included. But if there chance to be no lair within, there is no other way of catching the elk." For reference see n. 94 above.

[253] He wrote that the elk was like the roe deer in shape (*Gal.*, 6. 27. 1).

[254] A Greek physician at the Persian court towards the end of the fifth century B.C., who composed a history of Persia, a geographical work, and one on India.

[255] Pliny, *Nat Hist.*, 8. 75 and 105; Loeb 3: 55 and 79.

[256] *Hist. animal.* 2. 1; 501a21–b1; Loeb 1. 97.

[257] "lustra"; this word more precisely means "periods of five years."

[258] No wonder they were suspected of being leopards if their hide was "maculosus" ("spotted," "speckled"); tigers of course are striped.

[259] The 1550 edition includes here dicussion of the lion, and its account is amplified in 1554

There are also animals better known for their skins, such as lynxes, and many &733 of the weasel kind: various martens,[260] lardironi,[261] ferrets, piroli, hermelini,[262] genets.[263] Spain produces these, in their shape and lifestyle like the domestic weasels which we call ferrets,[264] with a varied pelt, and marked with black and ashy patches alternating. But sables[265] are of them all far more costly, through their beauty and scarcity. The Lapps produce these in the extreme North;[266] they are exposed to the sun, they are mostly hairless, because these animals live in shade, and where the Sun's power is quite weak. They are believed to increase the desire for sexual intercourse in women. And these are more distinguished than the skins of "marduri,"[267] with softer and thicker hair, and hair that keeps its position when turned either way. Each animal has very sharp claws and teeth, especially the sable. Each has a hairy tail, and uses it as a squirrel does, like a sail, so that it propels itself from tree to tree with a leap. They are especially plentiful near the Pole, up to thirteen degrees, because the region is inhospitable, and covered with stunted woods. Also, the pelts there are more beautiful and better, and their kinds are beyond counting, if you pay heed to the varied colours of the skins and the animals' nature and way of life—there is such an abundance of weasels. The skin on the neck is usually longer-lasting, as occurs in the fox and ferret and "sardirole";[268] nature has provided this part with a more solid skin, because it is at risk, and so it has come about that the hairs are retained longer.

Aristotle[269] denied that animals could possess pleasant smells, and so consistently that he states that the panther alone among certain animals smells good—but not in spring,[270] &734 and Theophrastus does not disagree with this.

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[260] "martes varii."

[261] Scaliger (*Exercitatio* 210(4) [674]) thinks this is a Lombard word, but is uncertain whether the creature differs from a "Pirolus" which is mentioned just after, or not.

[262] "hermelini" in 1560; Scaliger (*Exercitatio* 210(4) [674]) thinks the word is Swedish.

[263] "ginetae."

[264] "Foinos."

[265] "Zebellinae, alias sabellae"—a marten of the far North, especially the one now known as *Martes zibellina*.

[266] This and the following six sentences are new in 1560, and the subsequent one new in 1554.

[267] Scaliger (*Exercitatio* 210(4) [672]) says that these are distinguished by their white throats, and are of three sorts: Sebellina, rather silvery-haired; his local ones, more tawny; and Calabra, of a less saturated colour; the Latin word is "martes," a marten.

[268] Not identified.

[269] 1550 includes here description of an animal in Sarmatia like a sheep, and 1554 includes this material at 728 (1560) as that of an ancestor of the sheep.

[270] "The panther, after eating panther's-bane, tries to find some human excrement, which is said to heal its pain. This panther's-bane kills lions as well. Hunters hang up human excrement in a vessel attached to the boughs of a tree, to keep the animal from

But as the dung of animals is copious and moist, it can block the pleasantness of the odour; it is different[271] in plants, being moderate and dry and concocted. So in the animals that have sweet-smelling dung, it should be moderate, and dry, as in the great lizards of which we spoke previously, which we have also called crocodiles, and in snakes. Then, so that nature would leave nothing untouched, it took great care to make a sweet-smelling animal, and not just one, but on a basis of diversity.

So it fashioned the civet,[272] very like a cat, but larger—an animal which Spain produces, armed with teeth, very wild too, because it does not get less fierce over any length of time. With rather rough hair, an elongated mouth, like the badger.[273] In the genitalia of both the male and the female of this animal, it made a small bag from which semen is collected in a silver spoon— it is of such a [535]fragrant odour that even three grains outdoes a weight of several pounds of any very odorous tree. In such a struggle against a most difficult problem, nature did need to achieve something great; human beings too, at grips with a difficult problem, commonly try to achieve something deserving admiration, and when a limit is to be exceeded, we try to do it by a significant margin.[274] Nature has preserved the same rule in the case of the musk deer;[275] I only saw it dead in the street of the banners in Milan, though I have seen a living civet—indeed living ones, male and female. In size and shape and hair it[276] is like a roe deer, &735 except for being of a more blue-grey colour. However, its hair is thicker than that of a roe deer. It has a pair of teeth above, and the same below, and differs only in this and its odour from the roe deer; the divergence of hair could originate from the region, since animals that are moved to elsewhere bring forth sons much more different from themselves than in proportion to the divergence of hair through the region's diversity.[277] It is said that its blood is collected in a bladder below the navel, blood which overcomes and outdoes everything so far known in the depth[278] and attraction of its perfume. However, it is not brought pure to us, but the whole flesh crushed with the bones is often placed in quite old bladders,

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straying to any distance; the animal meets its end in leaping up to the branch and trying to get at the medicine. They say that the panther has found out that wild animals are fond of the scent it emits; that, when it goes a-hunting, it hides itself; that the other animals come nearer and nearer, and that by this stratagem it can catch even animals as swift of foot as stags" (Aristotle, *Hist. animal.* 8(9); 512a7–16; Loeb 11: 246–7; D'Arcy Thompson, not Loeb, translation used here).

[271] Reading "non ita" with 1554 instead of the "nominata" of 1560.

[272] "Zibethum."

[273] "meles"; "taxus" in 1554.

[274] "haud mediocri intervallo."

[275] "moschus"; *Moschus moschiferus.*

[276] The musk deer.

[277] Tortuous Latin has led to tortuous translation.

[278] "magnitudo."

and sold as genuine. The evidence is that everywhere in our musk little chunks of bone are found, and yet even like that it is so odorous that clearly animals of this kind were not known to Aristotle nor to Theophrastus. And it is not surprising that Galen too (for whom they were more relevant, and who lived more than four hundred years after them) knew almost nothing about them, though nowadays no ointment is without them. So I can barely tell how much of a pleasing odour the whole animal might release because of this bladder, even though (as I said) it was not only dead, but had been so for a long time already. And when that bag is placed for many years in store chests, all the clothes that are kept in them acquire a marvellously fragrant odour.[279] The musk itself is imported from Persia—there it is said to be of such a potent odour, if it is fresh and not adulterated, that if the bladder is brought near fasting nostrils, it coaxes blood at once from it.[280] Varthema [281] asserts that this happened to &736 four men one after the other. The result is that we believe only an adulterated product reaches us. It ages after a period of ten years.

As I have noticed, the slim, dusky, and very clever kind of long-tailed monkeys gives off an odour, unless the ointment sellers[282] have deceived me; they do not all smell of musk. The beaver's testicles do smell, but in the opposite way.[283] This animal is said to be the size of a dog, but elongated; it is tame, with dark shiny hair; I have seen its skin, which is reckoned among the expensive ones, and in this it differs from the otter,[284] which has rough long hair, while the beaver's hair is short. Tail wide, and extended like a sandal, but very fatty, hence it is also named "aluthra," which has a sharp hairy tail; the beaver's is said to be scaly. Legs short on the front feet, like a monkey, which they are said to use as hands; back limbs like a goose's, and thus it swims in water with the double assistance of its feet (the back ones) and its tail. It builds lodges from wood with marvellous technique; it uses the edge of its teeth (which are strong) just like a saw to cut wood. If its young are carried off, the female is said to break iron bars with its teeth and to eat itself[285] impetuously—it used to be tamed, and be brought up in the home. And they are said to have a king, whose tail is of this shape, although that of the others is blunt. Certainly huge herds now exist among the Muscovites, and it is found that there are wild ones, with unkempt skins, and

[279] The following passage ending at [C] on 738 (1560) is revised in 1560 from the 1554 edition, and in turn from the 1550 edition, in which there is some suggestion that one source may be beaver testicles.

[280] 1550, more lucid, indicates that the blood comes from the nostrils.

[281] Ludovico di Varthema, *Travels*, 102 (see n. 133 above): he reports this as occurring in Persia.

[282] "seplasia."

[283] "ex adverso."

[284] "luthra"; *Lutra lutra* (Linnaeus).

[285] Reading "se edisse" for the "sed edisse" of 1560.

ones that are slavish in their activity, as is said, and outstanding ones with softer hair, which we have seen &737 three-layered in pelts.[286] It has small testicles, like those of cocks, and hidden inside. This has such a smell that it is sold as a medicament. There is a humour which is to be found in the varicose channel,[287] curled like that of a roe deer, as is found in the species of cat which produces civet. This humour is initially like oil, and then congeals into the substance of honey. And these humours are bulky. We have also observed them in birds, as we have said elsewhere. A greater point too is what people say, that though they live beside water, they are hardly nourished by fish at all, but by leaves and bushes. If these[288] were not constructed, the beaver would have to differ in species from the otter. But if this is false, they will be of a single kind, although differing in tail and hair; this is clear enough. Whatever the truth of it, the otter's testicles have strength for the same functions as those of the beaver;[289] the beaver, originating in hot regions in the East, has much more potent powers. But the humour which is in place of semen, and the genitals themselves in any animal are extremely hot, and must be more so in the animals which because of their heat live beside and in water—such as the beaver and otter. It is characteristic of the otter to make its way against the flow of water, so that when it is full, it can return to its sleeping place with the current; all animals that do not readily find their prey, for instance wolf and fox and otter, when they come up with it, stuff themselves so full that they appear to burst, which does not happen to creatures that feed on fruit or vegetation, since their food is at hand everywhere. [C] These animals are &738 common to land and water, as is the crocodile too, but on an opposite basis to the hippopotamus;[290] indeed it is common to land and water, but is of the kind of fish, and they are included among the terrestrial animals. It lives in the Nile and Niger rivers. The Nile flows in Egypt and Ethiopia, the Niger in the part of Africa which lies between the Dark Head[291] and the green one, and is called Mansa.[292] A fish here has four feet, with short legs, the shape of a cow, and it walks on the ground. It has two protruding teeth three palms in length,[293] very

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[286] "et rusticos, quorum pelles rudes sunt, et opera servilis, vt affirmant, et nobilis molliore pilo, quem in pellibus triplicem esse animadvertimus, deprehensum est." The syntax is obscure; I have translated as if the text read, "rusticos [esse]," "serviles," "nobiles."

[287] The pampiniform plexus of the veins returning up into the abdomen from the testicle, forming part of the spermatic cord.

[288] Beavers' lodges.

[289] The beaver is now called "castoreum" but this is difficult to distinguish from "fiber," the word used earlier, and indeed the Linnaean name for the beaver is *Castor fiber*.

[290] "equus fluvialis."

[291] "Caput nigrum."

[292] This word is not in Leo Africanus.

[293] On the dimensions of a palm, see n. at 1080 (1560) in Book XVII.

like elephant tusks, but whiter, harder, and retaining their sheen longer, which makes them more expensive,[294] the crest and voice of a horse, which is the source of its name, hooves and ankle like oxen, turned-up snout, tail the size of a boar's, and viscera like those of a small horse or donkey; the thickness of the back is such that a hunting spear can be made from it. It is accepted that with such a careful description, Aristotle saw this animal.[295]

[536]People tame all animals at once when they are born, putting them to the breasts of women or bitches; in this way cats are made tamer, and accompany their master. But with training, otters have been seen that used on a finger signal to catch fish from a fishpool and bring them to the cook.

There is also a kind of uncommon monkey, tailless, face and penis the size and particularly the shape of those of a man, but covered all over its back with hairs.[296] There is no animal that so persistently stands, man alone excepted. It is fond of boys and women, like the men of its region, and when it has &739 escaped from its bonds, it tries to lie with them openly, behaviour we have seen. But it is wild, yet of such diligence that you would say that some human beings had less power of intellect[297]—not indeed our people, but barbarians who live in regions of inclement climate, such as Ethiopians, and some Numidians, and Lapps.

But let us move on to other things, among which is the nimble dog;[298] only the West Indies produce this animal, the size of a hare, but almost as plump as

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[294] The remainder of this paragraph appears first in 1560; and the next paragraph is revised in that edition, though elements of it are present in 1550.

[295] Aristotle did see this creature—it is the hippopotamus, and he wrote, "The Egyptian hippopotamus has a mane like a horse, is cloven-footed like an ox, and is snub-nosed. It has a huckle-bone like cloven-footed animals, and tusks just visible; it has the tail of a pig, the neigh of a horse, and the dimensions of an ass. The hide is so thick that spears are made out of it. In its internal organs it resembles the horse and the ass" (Aristotle, *Hist. animal.* 2. 7; 502a9–16; Loeb 1: 101–3; D'Arcy Thompson translation).

[296] 1554, though not 1560, calls this the Cercopithecus. The description seems to fit the chimpanzee; although it is asserted that the first contact of Europeans with a chimpanzee occurred in the 17th century (see http://en.wikipedia.org/wiki/Chimpanzee, accessed on 28 Mar. 2008), tales of chimpanzees might have preceded this time. But long before, Hanno the Navigator, whose work is known to Cardano (see n. 314 below), reported *gorillas* as "a savage people, the greater part of whom were women, whose bodies were hairy, and whom our interpreters called Gorillae." See http://en.wikipedia.org/wiki/Gorilla, accessed on 28 Mar. 2008.

[297] "ingenium," translated as "power of intellect."

[298] "canis levis"—this might also mean the light dog, or the smooth dog, etc. But it seems much more likely to refer to the Owl Monkey (*Aotus trivirgatus*), widely distributed in central and south America. "At dusk the woods resonate with the sounds of owl monkey vocalizations that include contented purrs as they begin sampling the first meal of the evening. On clear nights when the moon is full, the monkeys make loud hooting

it is long, it is so fat; it has very thin legs, so that when it walks, it drags its belly on the ground because of its weight; a very heavy body cannot be supported by extremely flimsy legs. It has four sets of claws, but on undivided, indeed interlinked digits on each of its feet, sharp, and hooked like those of birds, with which it climbs trees; and it barely walks on the ground, indeed for fifty paces a day, but it is bold at climbing trees. Small eyes and mouth, and so it does not bite; a rounded face, like an eagle owl,[299] a rounded neck, which it turns in various directions all round as though surprised. A crown of hair surrounds its face, which appears to elongate it, it has no tail, with hair between shiny white and ashy. Though all this is marvellous, it does not seem entirely at odds with nature. But because it appears to feed on air and dew, and because it calls practically all night with six tones always moving downward, so that the musical ratio of one and one eighth is preserved with a semitone in the middle—that is not unlike a total miracle.[300] By day it is silent, and sees little, so that of the four-legged animals &740 this is the only one that can be called nocturnal; there are others that can be, but nocturnal birds are more common: the eagle owl, the bat, the little owl, and a number of others. The reason is, that in the air there are not such obstructions to birds in flight as there are to quadrupeds walking on the ground. Also, that more trouble is needed to search for food by night than by day, especially trouble for the beasts that live by predation, at a time when the rest of them are lying low and are safe—through their own strength, like boars, or because their place is well chosen, like that of the nightingale between thickets and thorns, or because it is lofty, like that of ravens or crows in towers, or because the nest is narrow, like that of tiny birds,[301] or fortified, like that of foxes. An animal that needs to wander only by night should either possess wings or be consumed by hunger.[302] In fact cats[303] and wolves and foxes do search for food by night, as do roe deer, but the day concerns them as much as the night. And so there are birds we can call nocturnal, but no quadrupeds, apart from the

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sounds," but no evidence is available to support the musical assertions of Cardano here. (http://www.dumondconservancy.org/dc2005/web/aotus.htm accessed 21 Dec. 2006).

[299] "bubo."

[300] In the long-established "Pythagorean" theory of musical intervals, the difference between the consonance of the fifth (3:2 as a ratio of string lengths) and the fourth (4:3) was used to establish the tone (reckoned by dividing one of these by the other) as 9:8, and six whole tones of this dimension were reckoned to correspond to an octave (2:1), which they very nearly do: $(1.125)^6 = 2.0273$. Dividing one of these into two semitones provided the harmonic scale.

[301] "aviculae."

[302] "oportuit quod nocte solum vagari debuit animal alis esse praeditum, aliter fame consumi." Food being hard for a quadruped to gather by night, it would need to be a hungry quadruped; but a bird can get it more easily.

[303] "feles cative."

animal mentioned.[304] So although the distinguishing features of animals are very numerous, they can be reduced to two: those of the body and those of the soul. Those of the soul are tame and wild, nocturnal and diurnal—and this particularly in the kind of birds. There are also intermediates among the birds, such as the "qualea,"[305] which some, indeed most, people think is the quail, and the cock, and the ortolan; this bird is of an ashen colour, and larger than a goldfinch; it sings by night, and is known in Etruria.[306] Even if the ortolan sings at night, it cannot see then. Nocturnal birds are regarded as of ill omen, but not the intermediate birds. There is also a special distinguishing feature of birds: &741 some are identified by their song, some are mute, some are intermediate. The sarau[307] is the most distinguished of the singing birds, and is closest to the parrot. The parrot is the first of the talking birds, next comes the magpie, then the thrush, the blackbird, and the starling. The ravens are talkative too, and the solitary sparrows.[308] People hate sparrows because of their being alone,[309] and it is believed that one kept in a cage in homes, sing quite sweetly though it does, presages death. And people hate ravens for the same reason as they hate vultures, because these birds feed on human corpses. Three kinds of birds are reckoned unlucky: solitary ones, nocturnal ones, and those that cast longing eyes[310] on corpses. Birds are taught to talk at twilight and with a lamp, with hunger and wine; and they are selected when young, and for a wider tongue, and from among the parrots that have five toes on their feet; these are more suited to talking. Furthermore, hunger is the key link to compel them to learn, as Persius said:[311]

> Who equipped the parrot with his 'Hello' and taught the magpie to attempt human speech? It was that master of expertise, that bestower of talent, the belly—an expert at copying sounds denied by nature.

Darkness makes birds more attentive[312] and links sensation and memory. Hence people too remember and think and ponder better in darkness. But a lamp is

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[304] The material to [D] on 742 (1560) first appears in 1554.

[305] From Old French "quaille." The modern red-beaked quelea [*sic*] bird is confined to the south of Africa, and hardly likely to be this bird.

[306] There is instability about the gender of "avis" here: "Avis enim *haec* . . . in Hetruria *notus*."

[307] This is probably the "saru" mentioned by Varthema (*Itinerary*, 68, where the Persian word sâr meaning "starling" is noted.) as found in Calicut in India, and as singing better than the parrots, but as smaller.

[308] "passeres"; but this does not seem sparrow behaviour.

[309] Cf. Psalms 102:7: I watch, and am as a sparrow alone upon the house top.

[310] "inhiant."

[311] Persius, *Saturae, Prologus* 2. 8–11; Loeb 45. Cardano's text differs at three points from a modern text: he has "picasque" for "picamque," and "ingeniisque" for "ingenique," and "edi" for "sequi." I have used the modern (Loeb) translation.

[312] "sol(l)icitas."

introduced, because in carefully contrived darkness, birds sleep, and become fearful, so that sensation is expelled, not augmented—so a slender lamp is needed. Some people have tried to create forewarnings[313] with birds, like Anon of Carthage;[314] he caught a number of their nestlings and taught them to say, &742 "Anon is God." Then he released them into the woods, and used to hope that people would be drawn by this remark into superstition, and would agree to his being tyrant, as he was planning. He might perhaps have succeeded, but when the birds had gained their freedom, they forgot how to speak; he should have kept them for some time in freedom and then coerced them by hunger to produce the result he wanted.

[D]So to return to the cats:[315] because these animals were of an intermediate nature, nature gave them a blue-green glittering eye, so that they could see at night.[316] Horses too and wolves see better at night than human beings. To a human being, reason has revealed lamps; consequently, nature has omitted such great care for seeing at night as well. Hence the feline enlargement of the pupil is credited to a relation to the Moon. It is also noted how it looks less remarkable that human pupils alter not just on various days, but on one and the same day, so that they sometimes look large, and then smaller after a few [537]hours. By "pupil" I mean the dark part in the middle; the surrounding part differs between human beings and animals, and is called the iris. There are "pessi"[317] round the iris, and round the "pessi" the white of the eye. The interior angles are called the

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313 "praestigias."

314 This Hanno (not "Anon," a spelling perhaps due to the absence of a rough breathing for the A in the Greek version of the name used in Herodotus, *Histories* 7. 165) appears in the *Historical Miscellany* (14.30; Loeb 473–74) of Claudius Aelian, a Greek author in the 2nd and 3rd centuries A.D., who preserves some curious fragments of information. "Hanno the Carthaginian in his arrogance was not prepared to accept the limitations of humanity . . . He bought a large number of songbirds and kept them in the dark, teaching them to say one thing: 'Hanno is a god.' When they had mastered this one sentence . . . he sent them off in all directions, thinking to broadcast the birds' cry about himself. But . . . they headed for their native haunts, sang their natural song . . . without the slightest regard for Hanno." It is not clear which of the many Hannos of Carthage is referred to here, but perhaps the one referred to in Pliny (*Nat. Hist.* 8. 55) as the first lion-tamer.

315 1554 here, though not 1560, uses the late Latin word "*murilegus*" i.e. mouse-catcher, here for the cat.

316 The blue-grey colour visible in a cat eye is due to the colour of the *tapetum*, a structure lying against the outside of the retina, which bounces photons of light that have passed through the retina undetected directly back through it, providing a second chance for them to achieve detection. Thus the eye is rendered more sensitive, especially in the dark.

317 Although there is nothing in Vesalius's *De humani corporis fabrica* (1543) nor in Fernel's *Physiologia* (1567) corresponding to them in position or name, the word is cited from a grammarian named Pollux (see n. 319 below), as meaning the edge of the iris.

"fontes," the external ones the "he-goats"[318] or "paropiae,"[319] and the circumference of the eye the "Eon."[320]

But to return to the cat: there are various kinds, or else almost all the fierce and similar animals are in its likeness: the panthers, the lynxes, the leopards, the tigers. A shared feature is the size and strength of the claws, the hide with markings, varied and beautiful in colour, the head rounded; the face short, the tail extensive, body nimble, wildness; &743 and food acquired by hunting. A feature common to every animate creature is to feed on those from whom it is generated. Being weak at the start, where else can it get its food except from where it was born? But in the case of creatures generated from rotting material, the habit persists almost always, since they hardly attain any strength; in this way the little flies[321] feed on wine, and worms on filth, and caterpillars and the rest on the same leaves as those on which they were generated. Birds and quadrupeds with a harder muzzle, or with teeth already erupted, search for another kind of more solid food. When some animal is plentiful, as a rule nature generates another to feed upon it, with a double benefit: preventing a crowd of the first animal doing huge damage to the environment, and providing the benefit of food to those who feed upon them.

Thus, when ants are too plentiful in some parts of the West Indies, an animal is generated which they call an Ant Bear,[322] which picks them up with its tongue and devours them; and thus the animal is provided against a disaster for the region, since it does not seem ready for any other function; it is neither wild nor given to biting, and is called a bear more from its resemblance of body than from its strength or wildness. It disperses and demolishes with the humour of its tongue the most solid ant homes, and then with these demolished, it drags to itself and devours the creatures sticking to its tongue. In the case of other animals which could not easily become food, nature arranges &744 to prevent their growing into a vast multitude, either through the scantiness of their offspring, or

[318] "hirci."

[319] This word (Παρωπία) is according to *Liddell&S* used by Pollux (of Naucratis, who compiled in the second century A.D. a thesaurus of terms used in many subjects, including human anatomy) to mean the corner of the eye near the temple.

[320] Castelli (*Lexicon Medicum*) defines this post-classical Latin word as meaning "totus oculorum ambitus," citing only Gorraeus, a Paris physician whose *Definitionum medicarum libri XXIIII literis Graecis distincti* was published there in 1564.

[321] "musciliones"; this word is absent from Forcellini and DuCange, but *musca* means a fly, so Cardano has probably formed his own diminutive.

[322] This is a large anteater (*Myrmecophaga jubata*), native to South America and characterized by white stripes that run along both sides of its body.

the shortness of their lifespan, or their need for rougher air, or some difficulty in bearing or bringing up any offspring.[323]

But let us now proceed to the fishes.[324] They are sometimes found in hot sulphurous waters, as at Buda,[325] a town in Pannonia, and sometimes in alum-rich ones, as at Julium Carnicum.[326] There are huge creatures[327] in waters, especially in the sea, and more so in the Ocean, particularly in the torrid zone, since there the heat and the moistness make for growth, and the saltiness for preservation. The vast size of some, like the Whale,[328] is unbelievable,[329] and they bellow; they gush out so much water from orifices a cubit[330] wide near their noses that they overwhelm even very large ships. Very beautiful rods are extracted from their fins, which look like bone or horn; they are dark, like the horns of buffaloes, and so flexible that they never break; they shine conspicuously in the sun, so as to look golden.[331] Individual filaments belong to a single rod, and so there are very many rods in one fin; the fins visibly consist of rods. The mouth in the head is so wide open that you could make a small ship out of it. As Münster[332] says, they are sent to sleep by castor[333] diluted with water—they sink at once. It is probable that

[323] 1550 contains a paragraph here removed in 1554, on how to dispose of crocodiles.

[324] Siraisi (*The Clock and the Mirror*, 85–86) points out how Cardano's *De rerum varietate* contains a much longer account of fish than appears here, treating them from the standpoint of natural history, as well as their mostly marvellous or remarkable properties.

[325] Still one component of the modern Budapest, capital of Hungary.

[326] Zuglio, a market town near Udine in north-east Italy (*Orbis Latinus*).

[327] Reading "animantia" with 1550 and not the "animantium" of 1560.

[328] "Cete."

[329] The passage from here to the remark about the Orca in the next paragraph appears first in 1554, but 1550 here includes remarks about the turtle, removed in later editions, and then provides an earlier version of the account of polyps at 750 (1560) and then of the Mors.

[330] See n. in Book I to 26 (1560).

[331] This is baleen or whalebone, obtained not in fact from the fins but from plates that hang from the upper jaw of baleen whales. It is so elastic that it was once widely used as skeleton for women's corsets.

[332] See n. to 468 (1560) in Book VII. Münster (*Cosmographia*, Book IV, 832) wrote that in Spring the whole north coast of Norway is infested with whales ("balenae") of huge size, gathering to mate. Ships carried against their bodies or into vortices adjoining them are at risk. "Remedium est autem nauigantibus, castoreum dilutum aqua et in mare effusum. Hoc tanquam aconito petitus grex balenarum, totus repente dissipatur et in profundum fertur. Rugiunt horrendè": "Sailors have a remedy by diluting castor with water and pouring it into the sea. Assailed by this, as if by aconite, the whole pod of whales breaks up and makes for the depths. They roar horribly."

[333] "a strong-smelling substance obtained from the inguinal glands of the beaver and used medicinally by the ancients" (*OLD*).

fish hate the smell of the savage pursuer,[334] and so ships have this one protection against huge monsters; it is credible that the other ones can be terrorised by the odour of castor, as also by the noise of fiery devices.

There are other beasts too in the sea—monsters such as (among others) the Orcas,[335] which flies over the seas on two huge wings, bringing terror rather than peril to triremes. And sometimes these two match praetorian &745 residences in their hugeness. Hence comes that joke of Lucian in his *True Tales*.[336] There is a swordfish[337] in the Getic Sea[338] of such size that it swallows a seal. The seal is also known as the marine calf,[339] and is to be described later, because of its extraordinary shape. There is also in the same sea a kind of Orcas notable for its hump and its agility, called the "springual,"[340] which is thought to belong to the Orcas kind because of its huge size; fishes of the utmost and incredible size are called Orcades,[341] a name like the islands which lie near Britain in the Ocean. They are enemies of the baleen whales. The sawfish,[342] physeter,[343] squid,[344] and rota are all of the whale kind. While the word "ketos" in Greek means a whale, it also means vast and huge, hence "ketoeis."[345] There are also various forms of the same kind, such as the bearded fish, with twin horns, a back part narrower

334 Evidently the beaver, the source of the castor used to make whales dive.

335 The Orca (rather than Cardano's "Orcas" here) is nowadays the Killer Whale, a nimble swimmer with prominent fins.

336 A typically risqué Lucianic jest (*True Tales*, 2. 45): men serving as both ship and sailor, by floating face up in the water and using their giant erect penis as mast, holding the sails with their hands.

337 "ziphus"—evidently ξίφος (xiphos), meaning a sword, or swordfish.

338 The Black Sea.

339 "marinus vitulus."

340 At http://www.cummingmapsociety.org/mapsofelsewhere.htm, accessed 22 Dec. 2006, an Ortelius 1587 map of Iceland is mentioned referring to "STAUKUL. The Dutch call it Springual. It has been observed to stand for a whole day long upright on its tail. It derives its name from its leaping or skipping. It is a very dangerous enemy of seamen and fishermen, and greedily goes after human flesh."

341 The Orkney Islands to the north of Scotland.

342 "*Pristis*"; "Perhaps the sawfish, but said to be viviparous" (*OLD*). For further details see D'Arcy Thompson, *Greek Fishes*, 219. Pliny (*Nat. Hist.* 9. 2) refers to a *Pristis* in the Indian Ocean "200 cubits long," and in the note there to the translation, it is mentioned that some called it "vivella." While scholars appear unsure what the *Pristis* of antiquity was, *Pristis antiquorum* is now the official name for the sawfish.

343 A whale, but which is unclear (see D'Arcy Thompson, *Greek Fishes*, 280).

344 "Arbor"; tree-polypus; noted by Pliny along with the rota (*Nat. Hist.* 9. 8, 32. 144).

345 The Greek word for a whale is κῆτος. The (probably) related adjective appears only in Homer, as κητώεις. It had links to the meaning "gulf, depth, abyss" in compound Greek words, hence the remark here (see *Liddell&S*). And the Latin word for a whale ("cetus") seems to be the same word.

and shorter, a square head, the eye's circumference fifteen or twenty feet.[346] The rhinoceros fish too has a ridged back, and a concealed nose ending up in a horn; it has twelve feet, and devours crabs.[347] The cowfish[348] is also horned, and there is another with a totally bony body, and numerous others. But more marvellous than any other monster is Triton.[349] Pausanias recounts that he saw a triton in the temple of Bacchus among the Tanagrean peoples of Boeotia,[350] and another one among the Romans,[351] of which this was the form: Tritons have hair on their head like the little frogs living in marshes, reproducing the likeness both in colour and because the hairs cannot be split from one another.[352] The rest of the body ends in a thin &746 scale, and is provided with the same strength as the rhinas fish.[353] They have gills under their ears, and a human nose. Rather a wide mouth, and the teeth of a beast.[354] Their blue-grey eyes were visible to Pausanias.[355] They have hands too, fingers, and fingernails, like the small cavities of spoons. Under their chest and belly they have a tail instead of legs, as dolphins do.[356] It is said that many like this are seen in the Northern Ocean, but are allowed to go free, according to the fishermen's law—which I think is not

[346] "barbatus piscis," "oculi ambitus 16 aut 20 pedum." This may possibly be the Red Mullet ("mullus," "τρίγλη"); "the snout is blunt and steep, with two long mobile barbels present on the chin of the lower jaw," but there is nothing striking about its eyes, and it is not at all a large fish, 20–40 cm long.

[347] Creature not identified.

[348] "Vacca piscis." Boxfishes of to-day have scales fused to form a box round the body, only the mouth and fins being clear. The cowfish of to-day belongs to this group, and has twin horns above its eyes. But more probably what Cardano has in mind is the *Horned Ray*, a very large fish with protrusions on each side of its mouth, and known to Pliny and Aelian (on whom see n. 314 above). This is the more credible because the Italian name is "vacca marina." For details see D'Arcy Thompson, *Greek Fishes*, 34–35.

[349] Tritons in classical times resembled the mythical "merman" or male mermaid, and were "quite vague figures" of legend (H.J. Rose in *Oxford Classical Dictionary*, 2nd ed., 1095).

[350] Pausanias (*Description of Greece*, 9. 20. 4) does not say that he saw the Triton there; he says that "women of Tanagra before the orgies of Dionysus went down to the sea to be purified, were attacked by the Triton as they were swimming, and prayed that Dionysus would come to their aid. The god, it is said, heard their cry and overcame the Triton in the fight."

[351] *Description of Greece*, 9. 21. 1.

[352] It is clear from the original Greek of Pausanias that this is the meaning of Cardano's unclear Latin.

[353] In Pausanias it is the "rhine" (ῥίνη) fish, and there and at Plin. *Nat.* 32. 150 this is a kind of shark, probably the angel-fish.

[354] "dentes ferinos."

[355] He does say he saw them.

[356] From here the next two sentences are new in 1560

true, for if they proceeded in clusters, the obsessive[357] greed of kings would herd them together, regardless of danger, but if they were solitary, the rapacity of the fishermen would do this, constrained by no unease. But when they are seen on the surface of the sea, at any rate those that are of the whale kind, they presage serious storms, and they prowl in search of human beings especially. And there are in the Indian Sea near Borneo,[358] which adjoins the Equator, such large oysters that most of them contain flesh weighing twenty-five pounds, and some are found with flesh [538]amounting to forty-four pounds. Thus in the sea too all shapes of animals appear to be naturally created,[359] and not only of animals, but also of instruments. In the Indian Ocean especially there are monsters of vast and unbelievable size. I think the reason for the manifold shapes is the ease of generation and of life—since heat and moistness combine for generation, and food for life, there is in the sea plenty of heat and moistness, and food; there is salt in the sea, oil in the salt, and oil is moist and fatty, and hence is food too. Because of the motion, plague does not occur either, as it does in the air; the sea moves &747 every day, but sometimes the air is calm. The result is that any form of fish you fancy can easily be conserved—in the air it is not like that. Also, fish can move about in the sea without exertion, but terrestrial animals cannot;[360] so terrestrial animals have to go hungry, or be exhausted by extreme effort. The sea does not freeze or simmer as the land and the river water do, except at the edge where it is touched by the air. With so many advantages, as well as the mixture of diverse species, very many monsters are generated in the sea, so much so that sometimes when the sea wells up more extensively with the tide, up to thirty kinds of monster-forming animals are left on the shore of the Western Ocean. The same reason accounts for the monstrous and eighth-month births surviving in Egypt: creatures of feeble vitality can still survive in the sea. The fishes that do not survive more readily mate with others than do terrestrial animals, which feed on herbage, because they[361] copulate more conveniently. But those fish that consume flesh and other fish mate with more difficulty than the carnivorous beasts, because they have less power of sensation, which makes them do less loving; love comes with sensation; therefore fishes do not show pity, as lions do, nor spare any that occupy the role of prey.

They also say that the ray fish[362] helps a person in danger in the water to avoid sinking or being torn apart by sea beasts. But if the ray does this at the

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[357] "anxia."

[358] "Burnea."

[359] "effictae."

[360] It is not clear whether Cardano refers to their moving in water, or on land, but probably the former.

[361] The fishes.

[362] "raia"; but I cannot trace this story of the *ray*; the sea creature well known for its assistance to people in the water is the *dolphin*.

start, it does it from a special property; it is also alone among the seafish, as[363] we know, that interbreeds with another kind—the angel shark.[364] Next, the ray does not pursue living animals nor &748 (perhaps) eat flesh. The reason why the ray and angel shark alone interbreed together with a different kind, is that most of the other animals lie low in the depths of the sea. Carnivores, too, are after prey, not sex. Most of the peaceful fish are frightened to be trusting; such fish usually move in shoals, so as not to lack an associate of their own kind, particularly at a time when they are inclined to sexual activity. There are so many reasons why only the fish mixed from the ray and the angel shark is a form seen in the sea.[365] The same principle[366] applies to the size of beasts in the sea (especially the Indian sea) as to their form: because of the moistness and the heat, and food at hand almost everywhere, and also because they are supported without legs, and cover large tracts of sea without effort, fishes grow huge in comparison with land animals, and far larger than birds. Imagine an immense animal, four times as big as an elephant, if it can exist: surely it will need a great deal of food on land, and after consuming it, that big weight will have to seek other lands, with huge inconvenience. And thus it will easily perish on contracting a disease or starving, if it passes across gradually and slowly from one region to another. Again too, if it does get across safely and without effort, what will restrict its capture by human traps? None of these perils or handicaps is present in the sea; there is no lack of food for fishes, nor laborious passage from one region to another, nor in the midst of the sea could they be exposed to any human traps, even if a sovereign were in control of the whole world.

&749 Fish are consequently the largest of the animals, birds the smallest; the land animals are intermediate. The reason why the birds are smaller than the land animals is obvious: an animal is more easily supported on land by legs beneath it than it is in the air by outstretched wings. Lake fish are midway between land animals and marine ones. Thus in the region of Allgau in Bavaria,[367] the Vualmin[368] fish is found in the lakes; under its chin there are two cords,[369] which sometimes attain a weight of forty pounds. It hunts other fish with these cords, and even birds. These cords are in the position of the trunk in the elephant, and the fish can rightly be called "baleen whale of the lakes" because of its size; it is as much smaller than the sea whale as the lakes are smaller than the sea—and

[363] Reading "quoad" instead of the "quod" of the sources used.

[364] "Squatina." See n. at 644 (1560) in Book IX.

[365] Syntax unclear: "Ob tot causas solus piscis ex raia squatinaque mistus forma in mari cernitur."

[366] "ratio."

[367] "Algoia."

[368] This may be the catfish (*Silurus glanis*; German name Wels) which is present in German lakes, does grow very large, and has appendages under its chin.

[369] "funes."

the lake water is so cold, and the lakes so meagre,[370] that they are inferior to the sea for generation and feeding. So, as mentioned, nature has expressed the forms of land animals in fishes, the human being in the Triton, the woman in the Nereid[371] (Nereids are not fabulous, but Sirens[372] are), and the elephant in the elephant,[373] and others of this sort.

But though the front part of fishes looks like that of animals that walk on legs, the back part ends as a fish, with almost no exceptions. The reason is this, that just as in a ship's stern the tiller[374] does the steering, so the fish's tail sets its course. In consequence almost all fishes have a bifid tail. There is such an abundance of them that in Narbonensine Gaul[375] on some occasion so many and such large fish were taken in one sweep of the nets that they came incredibly to &750 390,000 pounds in weight, which could be the result of their size and profusion. The other kinds of living thing surpass the whole kind of fish in abundance, size, and strength, and in diversity of form, for instance among those that are not short of legs, such as the octopuses, so called from the abundance of their legs. Hippocrates used to recommend these, little ones roasted over charcoal, to assist conception,[376] and rightly, since the octopus easily conceives and carries young, and is provided with fibrous[377] substance, and is concocted slowly; this is why its head shifts away bad dreams, because something hard to concoct disperses black vapours just like onions, but much more strongly. Others are shapeless, like a thing with skin like pigskin, size nearly an elephant's, the head of a pig, straplike legs, toothless, small eyes, two openings under the belly near the tail. Tail very long, wider than an arm, the measure of an arm wider—a measure which individual ears fill out in length and

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[370] "ob macredinem"; "macredo" is not a classical word, "macies" being its classical equivalent, but it is formed (or Cardano has formed it) from the adjective "macer" in orthodox fashion.

[371] The Nereids of Greek mythology were the fifty attractive daughters of Nereus, the "old man of the sea," lived at the bottom of the sea, but came to the aid of seafarers in difficulty. One of them (Thetis) was mother to Achilles, celebrated hero in Homer's *Iliad*.

[372] The Sirens of Greek mythology were daughters of a sea god and sang very sweetly, so that mariners were enticed onto the rocks, as nearly happened to Odysseus and his fellows sailing home after the Trojan War. See Brumble, *Myths*, 312-15.

[373] Cardano probably means, "the elephant in the Vualmin"; the text is the same in 1554 and 1560.

[374] "temo."

[375] The southern province of Transalpine Gaul, i.e. Provence.

[376] "To produce conception, give, as hot as possible, inkfish roasted over a flame, very hot and half-cooked, to nibble" (Hippocrates, *Epidemics* 2. 6. 29; Loeb 7: 89)

[377] "nervea."

width, with a thicker skin than a [539]finger; many fish happen to lack teeth, as the sturgeon[378] does, but few do not take food.[379]

On the other hand, the mors,[380] which some people call the Rosmarum, is a fish of the seal[381] kind, from its hair, form, way of life, in Iachis on the north side of the Ocean near Muscovy; teeth so big that they make sword hilts out of them; they are very like ivory in their whiteness, but more solid, heavier, stronger.

There are also odorous fishes, like an excessive[382] kind of octopuses, and a particular species of flying beetles &751 among the insects—also among the birds, the hens of the West Indies, indeed more a kind of vulture; it makes for corpses and rotten things, but smells good, because of its powerful heat and the dryness of its temperament.

And there are fishes with marvellous powers: the electric ray,[383] which the citizens of Genoa call "tremorizam," and it is of the ray kind, because it has a mouth in the shape of the Moon. Touching it, or even touching the actual nets, numbs the hands, and soothes pains, but the fish's death undoes this great power. And the Echeneïs, one of the shellfish kind, named Remora in Latin—called "echinus"[384] because it stops ships by sticking to their bottom.[385] Thus it held up the trireme of the Emperor Caligula, with an ill omen for him.[386] It is like a

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378 *Acipenser sturio* is the common sturgeon of Europe and (like other sturgeons) has no teeth and is unable to seize larger prey. See http://www.vindia.info/s/Sturgeon.asp (accessed on 23 Dec. 2006), and n. 428 below. Further comments on this fish in the 1554 edition are removed in 1560.

379 "sed cibum non capere paucis."

380 The walrus ("morse" in modern English); the word is taken from the Lapp language (*Chambers' Dictionary*). In 1560 the passage is revised from 1554.

381 "vitulus (marinus)."

382 "nimium"—meaning unclear.

383 "Torpedo." In 1560 the passage is revised from 1554, and a sentence discussing whether it and the remora are the same is removed.,

384 As Cardano says here, "ἀπὸ τοῦ ἔχειν τὰς ναῦς," "from stopping the ships." For details of the tale and all those who have told it, from Ovid (Aristotle does not tell it) to medieval and later times, see D'Arcy Thompson, *Greek Fishes*, 67–70. And Copenhaver ("A Tale of Two Fishes") has disentangled in masterly fashion the accounts of the electric ray (torpedo) and the remora from antiquity through the Scientific Revolution, explaining how Cardano's confused account here was corrected by Rondelet, and Cardano acknowledged this subsequently in his *De Varietate*. Ficino too briefly mentions the tale (*Three Books on Life*, 325): "the little fish echinus is said to stop a great ship, and with only a touch."

385 Cardano mentions (Maclean, *De libris propriis* [1562], [305]) an attack on his account here by Rondelet (*Libri de piscibus marinis*) [Lyon: apud Matthaeum Bonhomme, 1554], fol., xv, 440). On Rondelet see n. 405 below.

386 Pliny, *Nat. Hist.* 32. 2: "out of the whole fleet, the emperor's five-banked galley was the only one that was making no way. The moment this was discovered, some of the sailors plunged into the sea, and, on making search about the ship's sides, they found

great slug,[387] and uncommon, so as not to be seen after these times.[388] They also say that in the river Arotan[389] in the blessed island of Ceylon,[390] which we will describe later, there is a kind of fish which evokes a fever when caught in the hand, and anyone who has touched such a fish is at once seized with fever. Such a remarkable story,[391] from uncertain authorship, is not going to command much credence; all the same, it is as remarkable as what was said above about the electric ray and the remora; souls are endowed with diverse powers, and all of the sea is alive, so they say, and swarming with monsters. And nature has had least to do[392] in the case of the animals that are generated there, to enable them to acquire sagacity or exceptional power of sensation, because of the quality of the place in which they are. Fish are in fact so dull of sensation that you can hardly tell whether to reckon many kinds of them among the animals or the plants—for instance the sponges and the sea anemone;[393] when &752 fastened to stones, they display no trace of being an animal, except that when pulled they contract themselves and show movement. This cannot perhaps be denied in parts of trees too, for instance dimly in the trunks of palm trees, and in the leaves of a tree, leaves resembling those of the mulberry, it is obviously and clearly seen—in addition to their having two feet. It is said that this tree originates in woods in the island of Limbulon beside the Moluccas, eight degrees away from the Equator, and has leaves that walk about if they are shaken from the tree and harassed for a week, and this tree is sensitive and is an animal—just as the sea anemones and the jellyfish and sponges are tree-like animals—even if the jellyfish are not to be included in the kind of plants.

Since movement depends on sensation in them too, in a hot region and a fatty soil there is nothing to stop parts of plants that often become detached possessing movement; the thin fatty moistness by which they are nourished can actually be the sort for these animals.[394]

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an echeneïs adhering to the rudder. Upon its being shown to the emperor, he strongly expressed his indignation that such an obstacle as this should have impeded his progress, and have rendered powerless the hearty endeavours of some four hundred men."

387 Pliny (n. just above) mentions this.

388 The material here to the beginning of 753 (1560) appears first in 1554, with an initial sentence removed later in 1560; this material is not in 1550.

389 Ramusio (*Delle navigationi et viaggi,* 1: 344f) recounts that this river of Ceylon, very rich in fish, has a fish somewhat like the torpedo, but its touch, instead of electrifying, produces a fever so long as it is held in the hand, relief being instantaneous on letting it go.

390 "Zeila."

391 "res."

392 "minimumque . . . laboravit."

393 "urtica"; can also mean "jellyfish."

394 Syntax unclear: "humidum enim quo nutriuntur, pingue et tenue, quale animalibus his esse potest."

But why are there not other immobile animals, apart from those in the sea?—there are so many kinds in it, and such abundance, for instance apart from the sea anemones and sponges, there is such a great host of shellfish, and so many diverse kinds of them, as there is of oysters. An animal has to feed, and so there has to be movement either by the animal or by the food; in water there is movement, and so there is movement in the food, and in the water which carries it along. Hence too animals born from fruit sometimes obviously lack motion (I mean progressive motion).

&753 Among the marine animals there are also some that do not move, such as oyster shellfish, in which nature is seen to have made marvellous play with a diversity of colours. The reason is that as trees and herbage each receive forms and colours according to their species, but the colours do not keep their abundance[395] of moistness later, thus because of their earthy substance, the colour stays and is strengthened in shellfish. There is also diversity in the fixed order of the furrow on the shell, since a small thing when varied and even casually mixed looks fashioned always in a fixed order, during the even growth of the intervals.[396] But a general feature of all the other animals is that their hooves and claws and hairs and horns and beaks follow the skin colour, though this is not always obligatory.

But to return to the sea: it is in fact itself the father of monsters. What stays immobile in salt water gets hard; thus oysters and shellfish and coral[397] do so—though the last is soft so long as it stays hid underwater. But why do shellfish harden, but not seaweed, which comes into being in the sea too? The reason is that seaweed grows, and thus cannot stand up to the sea's waves, and hence is created thin by nature, so that by compliance it escapes and keeps clear of the sea's assault. Shellfish and oysters stay on the bottom, and are made thick from the outset. We mentioned above why seaweed is soft, and it is agreed that on the contrary reasoning, shellfish[398] are hard.[399] The best fish there is the Manatee,[400] which can hardly be conveyed in a wagon by two oxen yoked together; its flesh emulates that of a calf so well that if you were not told it was fish, you would have sworn it was meat. This occurs because great heat concocts the moistness; it is actually &754 in this that meat differs from the substance of fish, because the moistness of the fish has been concocted by slight heat. It is said that in this fish's head there is found a stone very health-giving for renal stone. It has breasts, to which in a rare instance it puts the sons it has brought forth—it bears twins, a number corresponding to that of its breasts. There are people who call it "Boa,"

[395] Translating "abundantiam" instead of the "abundantia" of 1554 and 1560.

[396] This looks like a comment on the pattern on a snail's shell as the snail grows.

[397] See n. to 435 (1560) in Book VII.

[398] "conchas."

[399] 1550 includes a remark here about turtles, whose shells are enormous.

[400] The West Indian manatee or sea cow (*Trichechus manatus*).

because it has a head just like an ox, two (so to speak) arms, a flat back, a scale,[401] and a very tough skin; it can be trained like a dog, it is quite tame, and remembers its injuries. There is also a "Tiburo";[402] it is easy to catch because it is so greedy; it is of use because it is so big and has healthy tasty meat. It ranks among the greatest marvels of the sea, since there is a double genital organ in the male and a single vulva in the female; it has a double row of teeth, and it gives birth to a fish of its own kind, not to eggs.

The seal is much more of a marvel; it has breasts, and hair, and snores [540] marvellously while asleep on the shore.[403] The Spaniards prefer to indicate it by the name of "wolf." So large a number of people now assert that the hair on its skin rises and settles according to the sea's changing state, that our thanks are due to Pliny, the author of this statement.[404] But maybe it is entirely natural; in fact they are inflated by southerly blasts, and so are raised up, and are emptied by northerly ones, and settle; Rondelet[405] observed this. We possess a belt of its skin, which holds our sword on while we are riding. Its hair is lost slowly; the skin is like buffalo skin; the hair colour diverse, and it is like a lynx pelt to some extent. It is said that its right ear &755 placed under one's head procures sleep and maintains it. And this is the fish whose skin we said previously is not touched by thunderbolts.[406] And if all the tales about it are true, I doubt whether nature has done anything more marvellous—since the same skin if carried is thought to cure some diseases as well.[407] Leggings smeared with its fat do not let water in. And if the planks of ships are anointed with this, they are immune to ice. This is

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401 "squama."

402 A type of shark, *Sphyrna tiburo*, the Bonnethead Shark.

403 The following eight sentences first appear in 1554.

404 Pliny, *Nat. Hist.* 9. 42; Loeb 3: 191–92: "Its skin, even when separated from the body, is said to retain a certain sensitive sympathy with the sea, and at the reflux of the tide, the hair on it always rises upright": 1550 agreed, but 1554 doubted this statement, and instead of the Spanish name "wolf" stated that in Hispaniola it was called "Lobus," and did not cite Rondelet.

405 Guillaume Rondelet (1507–1566; zoologist and later professor of medicine and anatomy at Montpellier in southern France; Cardano disliked him and in his *De vita propria* [chap. 48; trans. Stoner, 253] stated: "He mentions my name in a derogatory manner"). Rondelet wrote (in his *De piscibus marinis*, Bk. XVI), citing Pliny (*Nat. Hist.* 9. 42; Loeb 3: 192–93): "Corio autem mortuorum ventorum mutationes significantur: austrinis enim ventis insurgentibus pili inhorrescunt, et surriguntur, in Boreali constitutione ita desidunt, vt nullos esse affirmes, id quod saepius obseruaui. Quo fit vt id verum esse credam, quod Plinius scripsit."

406 Cardano mentioned the immunity from thunderbolt conferred by sealskin in Book II, 102 (1560). Pliny (*Nat. Hist.* 2. 146; Loeb 1: 283) said that thunder never strikes the laurel tree nor goes more than five feet into the earth, and because it never strikes a seal, tents made of sealskin provide protection.

407 The next 11 sentences were first introduced in 1560.

also a feature common to every kind of whale. Olaus Magnus[408] says that skins anointed with it are not gnawed by mice, and therefore horse harness is regularly anointed with it. For this purpose[409] there has to be a smell. Seals are particularly damaging to anchovies,[410] of which they consume a huge number. The seal should be thought to be long-lived, being large, sanguineous, and a creature that breathes.

They are seen to defer to their elders, who as they go down into the sea are followed by their juniors; the young and the old usually live separately on the shore. When one of a band[411] is captured or is struck, the others follow so as to bring help, like pigs, whom they resemble in voice too. This exposes them to the wiles of fishermen, who dress in a dark skin and imitate the voice of the female seal, and entice many males into traps. Almost every sea has some kind of them, but there is little difference between those found in the Mediterranean, and the Southern and the Northern Ocean and elsewhere, as is the case with pigs. It is said too that they are trained, and capable of instruction, and recognise their acquaintances, and have sometimes greeted people at Rome with lowing and a gesture, so that nature (like fortune) has denied some of them everything, and granted it to others.[412,413]

&756 But[414] nature appears to have denied nothing to the whole kind of the fishes, except refined power of sensation; granted that legs would be of no use to fish for swimming, and hence advantageous to few of them—still, nature has granted legs to some of them as well, either to walk on the bottom of the sea or on the shore—or as weapons, or to stick more firmly to rocks in storms, or as hands, like the claws in crabs. And legs appear to have been given for all these reasons to octopuses, crabs, lobsters, and crayfish[415]—and that is why they swim slowly. In a small spring at Lyons we saw little fish with two legs in front, as if under their armpits. There were also true fishes, which I would have happily called mullets[416] because of their big heads, which resemble those of frogs, with in fact a wide, low and large mouth. It seems that nature has enabled them

[408] See n. at 637 (1560) in Book IX. The statements are in chapter six of book 20 of Magnus's *Description of the Northern Peoples*.

[409] "In causa."

[410] "halicibus."

[411] "è sociis."

[412] "aliis omnia negasse, aliis concessisse."

[413] "Yet they are capable of training, and can be taught to salute the public with their voice and at the same time with bowing, and when called by name to reply with a harsh roar" (Pliny, *Nat. Hist.* 9. 41).

[414] This paragraph first appeared in 1554.

[415] "squilla." Just before, "gammaris, tum locustis" has been translated simply as "lobsters," since no clear distinction could be reached between the two.

[416] "capitones"; mullets were so named because of their big heads, "capita."

to take food more unhesitantly from the water's edge.[417] Do they belong in the number of frogs coming to birth? Is this the Cordylus of Aristotle?[418] But the Cordylus has four legs.

On the other hand, the fish called Vivella, and by others Pristis,[419] is of no use, although it is large, because its flesh is not pleasant, but its form is remarkable, like one carrying on its forehead a cartilaginous thing like a sword, four or more palms[420] long, provided with sharp strong teeth from top to bottom. Belon[421] called it the Saw,[422] and says it has fifty-eight teeth. I have often seen the saw, but never the fish. Flying fish come into being there too; they are &757 small, and winged, they have long wings near their gills, the fish themselves being a palm larger, and so long as they are moist, they keep the fish up, but when they dry, they let it fall. They go about in shoals, and are at enmity with the Oratae.[423] Many of them are found near the island of Bermuda or Garza.[424] I am aware of many kinds of these.

Fish are trained very little, since they are of small and dull intellect; then dolphins are very capable of taming, and are also the fastest of fishes, being the most talented, and having an acquaintance with human affections, especially that of pity.[425] In the same way, almost all the birds are tamed. Among the quadrupeds, being of medium talent between birds and fishes, some are tame, some not. Fear stops some being tamed—for instance the mice and hares; how will

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[417] "ripa."

[418] The Cordylus was probably the larval form of some triton or newt, such as *Triton alpestris* or *Salamandra atra*, which retains its gills till it is well grown (D'Arcy Thompson). Aristotle (*Hist. animal.* 7 (8), 589b27–9; Loeb 11: 77): "this creature is furnished not with lungs but with gills, but for all that, it is a quadruped and fitted for walking on dry land"; (*De Part. animal.* 4. 13; 695b25–27; Loeb 419): "The Cordylus, however, has feet in addition to its gills, since it has no fins, but only a scraggy flattened-out tail."

[419] See n. 342 above. This word was introduced in the 1554 edition..

[420] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

[421] Pierre Belon (Bellonius; 1517–1564) was a French naturalist who travelled as far as Syria and Egypt, and first showed the homology between the human skeleton and that of birds, thus inaugurating modern comparative anatomy. But I cannot find the Serra sawfish with 58 teeth mentioned here, either in his *Observations de plusieurs singularitez.* of 1588 nor in his *L'Histoire naturelle des estranges Poissons Marins* of 1551.

[422] "serra." These two sentences first appear in 1560.

[423] "Orata" or "Aurata" is the "gilt bream" or "gilt head," a fish with a gold band between its eyes. For full details see D'Arcy Thompson, *Greek Fishes*, 292–94.

[424] In 1511 an island named "Bermudas" was depicted on a map in Spain. The Spanish navigator Fernández de Oviedo sailed close to the islands in 1515 and attributed their discovery to his countryman Juan Bermúdez, possibly as early as 1503 (*Encyclopedia Britannica*).

[425] Brief comments on their nose and mouth in the 1550 and 1554 editions are removed in 1560.

you actually be fond of someone who you are convinced is plotting against your life? But those who are in fear convince themselves of this. This is why, even if tyrants do much good to many people, no one is fond of them, because of persistent fear. This is what happened to Nero—and do not suppose that Nero was not a blessing to many people. And so fishes can hardly be tamed, and not much, because of the crudeness of their talent and the difficulty of managing them; as I said, usually fear is present as well. Since the dolphin has a powerful talent, and is very bold, and breathes, and so can be managed to advantage, it has to be either the only fish that is tamed, or much more so than all the rest. If it can be transferred into fishpools, it differs little from a dog in tameness.

After[426] we came to discuss the mice, something needs saying &758 about them and their kinds, which are very numerous, with more searching enquiry into the principle—since animals are distinguished in a number of ways, we have explained that distinguishing features are also derived from the difference in foods—in general herbage and trees, then flesh, and particularly in four ways: either they feed on the moistness among the elements,[427] or like the chamaeleon on air, or like the "sturio"[428] and many other fishes on water, and like toads on earth; though in fact they eat earth, the earth is not food for them, but that little fatty moistness that is contained in earth. Or they feed on plants, as solipeds[429] do, and most of the horned animals too, and these are more distinguished than the previous ones; or on flesh, as lions and dogs do, being more outstanding than both the preceding ones. A fourth kind feeds on [541]fruit, and this is the most distinguished; in this kind are the human being, the elephant, the pig and bear, also mice, and all the birds except the carnivorous ones—they all in fact feed on seeds and fruit. All of these, except the elephant, also consume flesh, apart from the birds, some of which (hens, and magpies, and crows) are nourished by flesh.

Animals that feed on flesh also consume eggs, milk, and blood. So all such enjoy carrion only, and apart from the birds, do not kill anything; the birds that use flesh consume the same animals, even alive if possible, as hens consume worms. Since the smaller ones of these, and those like the wild ones, are in cold regions, and in temperate regions recollection remains of the very large Erymanthian Boar, which used to lay whole &759 regions waste,[430] it is strange that they are very small in hot regions—we in fact have Indian ones that are like the

[426] The material here up to [E] at the end of 762 (1560) appears first in 1554.

[427] Four elements, or for Cardano three; the case for three is argued at the start of Book II at 74–75 (1560).

[428] Mentioned above at n. 378 ; evidently "sturgeon," but the usual word for this is "acipenser."

[429] Animals with a single hoof on each foot, such as horses, mules, and asses.

[430] The capture of the boar of Mount Erymanthus was the fourth of the twelve labours undertaken by the mythical Greek hero Hercules. See Brumble, *Myths*, 156-60, at 156-57.

others in form, voice and way of life, and also in uterine gestation; they are delivered in two months, not in three weeks like rabbits, yet are a good deal smaller than rabbits. Their flesh is tasty, and they do not bite, nor are they tame, but they run extremely fast, like most of the small animals. They do not die easily, as rabbits do, and they drink only occasionally, and sparingly. Their life is short, and they die of the cold too. And so I would not dare to call them Indian, but instead (because of their dryness) small, because their origin is perhaps from Africa. Heat cannot stand in the way of size, nor can moistness, but cold or dryness; this is why they die of cold, and do not drink. They feed mainly on cabbage, bran, and oats. They also rear up, at variance with the practice of the others, and like rabbits they consume their fetuses through lust.[431] They have sets of five digits, and six or even more on their feet; quite soft hair, the colour of every kind of quadruped; they have a mouth, not a beak, and genitalia concealed inside. Teeth of the rabbit sort, and they bear fully-formed[432] fetuses, as pigs do; the newborn accompany the mother at once (they generally bear three in a litter). Eyes like those of mice, so that some people regard them as Indian mice, but since they are almost without a tail, you would call them, so to speak, a mixed kind.

But though I had planned to have dealt with mice, I had moved over to pigs—not overlooking this, that each of these animals alters its size through the plenteousness or scantiness of its food while &760 being weaned, as dogs and pigs do too, and all the others. And so, back to the mice. It is no commonplace story, such an unimportant animal, when nature plays its game so exceptionally too with tiny things. Indeed it is primarily so fertile, as Theophrastus records, that in Persia female mice conceive even in the womb of their mother[433]—completely incredible, unless easy procreation is linked rather to usefulness than to distinction; everything very unimportant is begotten very easily, and brought to completion, both very fast and in every way. The elephant or the dolphin or the human being are not like that. And so they are so much multiplied by rain that it is hard to tell which is the greater marvel: the ease with which their kind is propagated, or with which it dies—they die no less quickly than they grow. As mentioned, the reason is obvious: everything very unimportant is generated by its own refuse and rubbish, and in the same way they die from any tiny cause; the ease of death and of generation are the same. For their being easily generated there is a single reason: that they are easily brought to completion. In every kind, the small and weak items are the ones that are easily brought to completion. Hence it is that sort that must die easily, which is to be understood not only in the case of species but also in the case of individual human beings; the human

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[431] I.e., to free themselves to copulate and start another litter.

[432] "absolutos." In the description here, 1560 amplifies the account of 1554.

[433] Aristotle reported this (*Hist. animal.*, 6. 37; 580b28–30; Loeb 2: 349): "There is a place in Persia where when a female mouse is cut open the female embryos are seen to be pregnant," but I have not traced it in the works of Theophrastus.

being appears as a single species, not in its eternity or its importance,[434] but in its potentiality and its perfection. In Giaro,[435] an island in the Archipelago, it is said that the mice eat away metals and kill any trees touched by their teeth.[436] This is evidence of some rabies and of excessive dryness. &761 The reason that they are brought to such great dryness is that they are very easily altered—because they are very weak by nature; they acquire and retain power because otherwise they are complete and sanguineous.[437] There are innumerable species of them, tame ones, wild ones, squirrels (so called because of the size of their tail),[438] dormice, and the "avellanei," smaller than the rest,[439] which sleep all winter. The alpine ones, which the Milanese call marmots, are included in this kind. A general characteristic of the alpine ones, the squirrels and the dormice and the "avellanei," is that they are tame. Also, they all sleep in the winter, apart from the squirrels. But the "avellanei," which live among filbert shrubs,[440] are red. Squirrels lie low in winter, rather than sleep. It is also a general characteristic of all these that they eat sitting up, using their front limbs as hands. Dormice get very fat in winter, so that they appear to be growing fat through sleep rather than food—though they often hide away in the trees a huge stock of chestnuts and other nuts. With the help of their tail and their light weight, squirrels are nimble enough to leap from tree to tree. They[441] swim across rivers, using their tail as a sail and supporting themselves on twigs; the meat of those that are caught near the Pole[442] is tasty, since there they usually grow fat. It is believed that their teeth serve as an amulet when hung on, for divination. The alpine ones, the largest of all, are quite sagacious, having nothing apart from their name in common with the mice. In the mountains they have one of their number as a lookout, who warns the group while they are otherwise busy gathering brushwood; they gather flexible bits from this, and lie back while clinging to them with their feet, then one of them is &762 loaded and lets himself be pulled along by the tail by another one, like a wagon, so that he pulls away his bedding with him, which he could not fetch in any other way. It is believed on clear evidence[443] that when they

[434] "nobilitas."

[435] Another name for Stapodia, a small island in the Cyclades in the Aegean Sea, about 200 km SE of Athens.

[436] "referunt metalla erodere, et arbores dentibus tactas occidere."

[437] "sanguinea."

[438] Reading "sciuri à caudae magnitudine vocati, glires . . ." instead of "sciuri, à caudae magnitudine glires . . ." of the sources. The squirrel derives its name, *sciurus*, from σκιά, shade, and οὐρά, tail; hence also the French écureuil. .

[439] "avellanei reliquis minores"; "avellaneus" has not been traced as the name of an animal of this sort, and should mean "connected with hazel(nut)."

[440] "corylos."

[441] Two sentences here first appear in 1560.

[442] "Iuxta polum capiuntur." This is difficult to account for.

[443] Reading "evidenti ratione" instead of "evidendi ratione."

are getting extremely fat, and are minimally unpleasing items in food, their meat contributes a great deal to obtaining sleep.

The squirrels too are very tame, but the dormice and the "avellanei" hardly at all—they are so small. The "cusetae" (this is what our fellow citizens call squirrels) seem diametrically the opposite of the alpine ones—the alpines are slow of movement, and fond of resting, but squirrels are never at rest—so that their flesh has to be excessively hot and dry. A mouse has recently been brought from Asia which people used to say was Indian, precisely like our mice in its mouth and tail, but of the colour and size of a "taxus."[444] [542]The "taxus" or "meles"[445] is larger than a fox, of the colour of ash, with long hair, wide open jaws,[446] given to biting with its very sharp teeth. And so, to return to the mice: we have seen very shiny white ones; in fact they go gray in old age; they turn out white in the cold too, and through white food. [E] Olaus[447] says he has experience of sugar—he thinks bees are dark through being nourished by a single food; and wasps are varied in colour, through having varied food.[448] However it is, weak creatures change a good deal in response to food, in their colour, their body, and their way of life.

Another point to consider is what happens in the sea just as on land: there are regions in it that are lifeless and others that are rich in fish; in some food is plentiful, in others there is none; also, different kinds of land impregnate waters with varying smell and taste, &763 and fishes either seek them out or avoid them. Shores are often rich in fish, because of the feeding there, and so are eddies, because of their security.[449] There is such a great difference between waters in the sea, that near India, nearly three hundred miles in a straight line for Ethiopia, the sea is white like milk, elsewhere it is blue, elsewhere dark, elsewhere green. The white colour is when white sand underlies a shallow sea; the green when the sea is of medium depth; the blue when it is very deep and is in motion; but if it is at rest, the colour is silvery. When we were going to Paris,[450] we saw in the Verbano lake[451] a portion near us among the undulating waves of the whole lake that was immobile and of a silvery colour, though all the rest was blue. The reason is that the wind is hindered by a mountain summit, just as a shadow is bounded by

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444 One word for a badger.

445 Another word for a badger.

446 "rictus."

447 These two sentences appear first in 1560.

448 In his *Description of the Northern Peoples* (book 18, chap. 10) Magnus offers these opinions about bees and wasps, and says that he has "seen mice that continually nibbled white sugar take on a white colouring and shed it again after the sugar had been removed."

449 The rest of this paragraph and also the next one first appear in 1554.

450 Cardano was going to Paris in 1552 on the way to Scotland to treat Archbishop Hamilton of St Andrews. See Morley, *Life of Girolamo Cardano of Mila,* 2: 89 ff.

451 Lake Maggiore, some 50–100 km NW of Milan in Italy.

a height. On the part that was pressing towards[452] to the mountain (calm was not reaching the mountain's root), it took its start, where its impact was slowing close to the rock; being forced to the sides by its impact, it was stirring up the part in the middle. And the water is dark whenever dark sand underlies shallow water, or when the depths are in turmoil. The same thing happens to fish out of water as happens to human beings out of air; it is reported that in Calicut, which is both a city and a region in India, the plague never rages—I think because of the temper of the air and the healthiness of the food—and perhaps because of restraint in eating. Similarly, in some parts of the sea fish abound, because the food there and the water are very healthy. &764 There is not in fact a question[453] of how they live for us to debate in the case of fishes, since to make a mistake over that is appropriate for a human being only.

On the same basis, the air abounds in birds—the other air, so to speak, becomes lifeless. A profusion of birds of every kind is evidence in a twofold way of the healthiness of the air, both because they themselves detect the qualities of the air, and also because it supplies food too. But this indication ought to be related to regions, not to their parts; it is in fact possible for there to be abundant birds in a valley, although the air there is heavy in comparison to plains and hills. But hills and plains will secure healthiness of the air. Hence in the Molucca Islands at the time of the equinox a dead bird is gathered on land or sea which is never normally seen alive, since it has no legs, even though Aristotle denies that any bird has no legs.[454] This bird I have happened to see three times,[455] and is, so to speak, the only one to lack legs, for the reason that it lives in the upper air and far from any human view. Its body and beak are of a size and shape like the swallow, the wing and tail feathers outdo those of a hawk in size, with wings extended, and almost match those of an eagle. You can work out the thickness of the feathers: it is what reason suggests as suited to such a small bird. So they are very thin, and apart from their thinness, entirely like that feathers of peahens; they are not like those of peacocks, not having eyes such as are seen in the tail of the peacock. The back of the male of this bird is curved inward, and reason itself

[452] "vrgebat."

[453] "ratio vivendi."

[454] The bird of the Moluccas with "no legs" is the Bird of Paradise, on which see n. 1 above. The general tale of a "legless bird" starts with the Greek bird name ἄπους, "no leg," meaning a kind of swift or swallow (D'Arcy Thompson, *Greek Birds*, 53–54), but Aristotle (*Hist. Animal.* 487b24) refers to the bird of this name as κακόπους, "not good on its legs." Pliny (*Nat. Hist.* 10. 55) says it got its name by not having *the use of* legs. Another Greek bird name, χελιδών, means a swallow, but can refer to a swift or martin (Thompson, *Greek Birds*, 314–24). Cardano's Latin word here, "hirundo," indicated a swallow, or other martin-like bird (*OLD*). Hence it could indicate a swift, a bird celebrated for descending from the wing only for purposes of reproduction.

[455] "Haec igitur cum ter videre iam contigit": translation speculative.

tells us that it creates female[456] eggs into that &765 cavity, since the female too has a concave belly, so that she can incubate eggs in either cavity.[457]

In the male, a thread sticks in the tail longer than three palms,[458] dark in colour, midway between a square and a round shape, and neither thick nor very thin, but not unlike that one that cobblers use to sew up sandals. We suppose that while the female incubates eggs, she is linked quite firmly to the male; and it is not strange that she lives all the time in the air, for with her tail and wings outstretched in a sphere, there is no doubt that she is suspended of herself. If some weariness occurs, a change can throw her off. I think she gets no food except the dew of heaven, which is at once food and drink,[459] and thus nature is seen to have arranged so wonderfully that she can live in the air. But I think that feeding on air is unlikely, because it is too thin. Feeding on tiny animals?[460]—not that either, because their assembling, surely essential for generation, would not occur there, and they are not seen in the bellies of birds, as occurs in those of swallows. But this is not conclusive, since it is believable that Manucodiatas[461] are killed off by old age alone. Not feeding on vapour either, since it is more abundant lower down, and they would be seen coming down from there. Furthermore, sometimes vapour is destructive—so it is likely that they feed on dew during the night. Like the Bird of Paradise, it is a sort of bird that does not inhabit the ground at all; contrariwise, the ostrich never leaves the ground, so that you could not call it a bird unless you paid heed to its form. It got its name,[462] I think, because it &766 imitates the camel in the length of its neck and legs; it is actually a little taller than a human being. A small sparrow is called "strouthio" in Greek,[463] the name created, so to speak, by irony, as if someone were to call a pigmy a giant, or a tiny man huge. The ostrich belongs to the bird kind, but has a neck of camel's size, beak, eyes, and head of a goose, but they tally with its particular size; wings and tail with feathers of diverse colour—ashy, shiny white, dark; these three colours, since they do not glint much, are native to them;[464] a reddish colour is uncommon and barely visible. Yet there is no other bird like that, nor is

[456] "foemina"; presumably "foeminea" is meant.

[457] The meaning is unclear, but may be that incubation could occur below the female or on the male's back.

[458] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

[459] A passage here in 1550 on the chamaeleon is absent in 1554 and 1560.

[460] "animalculi."

[461] Birds of Paradise; they were supposed to lack legs. See nn. 1 and 454 above.

[462] "struthiocamelus."

[463] More correctly, "strouthos" (στρουθός) but in Greek ultimately the ostrich influence triumphed, and στρουθός came to mean an ostrich (*Liddell&S*). Scaliger (*Exercitatio* 230 [724]) denies that the ancient στρουθός meant a sparrow; he states that it meant "gallina"—a hen.

[464] "sunt in eis nativi rubei rarus et uix conspicuus,"; the translation is speculative.

there such prettiness or beauty in the feathers of any of the birds, so that soldiers do not deck their helmets with any others. While there are people who fasten the wings and the tail of the Bird of Paradise to their crests because it is rare, there is also a superstition that anyone [543]with one does not get wounded in war. So their body is covered with rare plumage—and their legs with rarer, so that they look like human legs, not bird legs; in size and roundness and in being tapered near the knee (not much, but little by little), they imitate a human thigh with white flesh, since they have no feathers there. Cloven feet, like those of oxen with hooves, a leg like a goose's, but of proportionate size, a slow gait. The one I saw was gentle—I do not know the behaviour of the others. They lay eggs the size of a baby's head, rounded, and as these age they imitate ivory. They are often hung up in temples, and in fact remain there a long time, because they are very hard, and when the liquid[465] is extracted, they get like bone. It has lashes in its upper eyelid, it runs as fast as a horse; &767 people say a horse keeps away from one and does not risk looking at it; it runs with its wings uplifted, yet does not fly, and is said to brandish stones with its feet, and to digest iron, which occurs because of the violent heat and thickness of its stomach, and to brood eggs with its eyes; but it does not brood them, it simply looks at them;[466] the young are actually hatched by the Sun's heat. I have never heard its voice. It is surely the largest of the birds, if it is properly called one.

The largest of our own flying creatures,[467] and the one everyone fears, is the eagle—known to everyone, and very noble. It is much larger than a goose, especially with its wings and tail rather than with its body and its weight.[468] It feeds on snakes, too, and sometimes is overwhelmed by them, is entangled, and falls down. The nobler ones can gaze at the Sun without blinking. But in Iurrha in Scythia there is a "Bialozor"[469] bird which is shiny white under its belly, with a sort of brightness, in its wings and tail even bigger than the eagle, and the other birds are so afraid of it that even the eagle itself is prostrated at sight of it, though its body does not exceed the eagle's.

In India there is said to be a predatory bird, much larger than an eagle, dark and purple, with white feathers interspersed. Its beak is tawny, and marked with blue or scarlet colouring, so prettily that nothing nicer could be seen. And so because of its prettiness and size, sword hilts are regularly made of this bird's beak; it is known that the beak &768 has to be very hard. It is accepted

[465] "humor."

[466] A legend widespread in the Christian East, where ostrich eggs are suspended in churches to symbolize the steadfast gaze of faith. Cf. J.W. Spargo, *Virgil the Necromancer* [1934] (Boulder: Kessinger, 2004), 96.

[467] Scaliger (*Exercitatio* 231 [715]) denies this and says a swan is larger.

[468] Two sentences here are first present in 1560.

[469] This word now denotes in Polish the bird "falco rusticolus"; see http://www.runde.no/fugler/polfugler.htm, accessed on 23 Feb. 2008.

as the largest of the flying birds. It is thus necessary for such birds to have huge wings—the bigger and harder they are, the faster they fly. It is better for the wings to be middle-sized if soft, since bigger ones bend and get in the way—as in swans, which differ from geese almost only in their size, although they are shiny white all over, and of all birds sing the most sweetly; their voice is that of a goose, as I have often assessed it by ear. This kind of birds, so much praised, tears its fellows to pieces and consumes them, but sings sweetly even at death.[470] Hence Ovid's words:

> Cast down upon the damp grass, the white swan sings at the waters of Maeander, where the fates summon it.[471]

There is a kind of birds teeming with fish, and notable in the West Indies for the size of its beak and body, called the Alcatraz,[472] marked out by an ash-coloured and saffron plumage, with the beak two palms long[473] and coming to a point. However, the beak of the stork and crane are not far short in size. The woodpecker[474] has a beak bigger than its whole body, but its body is a little bigger than that of a quail. Its beak is rather long, wide where it is linked to the head by three digits, curved; it bores holes in trees with it, and protects itself prettily against the tailed monkeys there by skill and its beak, though it is quite small. There is this remarkable feature in it, that it has a feather instead of a tongue, and here it differs much from the nature of other birds. It whistles strongly, and the same territory feeds it as feeds the Alcatraz.

And[475] among the grand birds there are the vultures, for giving an augury to Romulus,[476] &769 for their size and scarcity, so much so that some people[477] state that their nests have never been seen, though very many nests are visible beside a stronghold, on the crags of the part of England now called Scotland. This vulture eats flesh, yet does not kill any animal, and for that reason is regarded as sacred.

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[470] Compare Ovid, *Metamorphoses,* 14. 428–430: "In tears she poured out words with a faint voice, lamenting her sad woe, as when the swan about to die sings a funereal dirge."

[471] Ovid, *Epistulae heroidum,* 7. 1–2, ed. Dörrie: "Sic ubi fata vocant, udis abiectus in herbis / ad vada Maeandri concinit albus olor."

[472] Albatross, or other large bird such as the frigate-bird or pelican.

[473] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

[474] "Picus," but 1560 reads "picutus."

[475] The next two paragraphs first appear in 1554.

[476] Romulus and Remus, traditional twins, disputed over where the site of Rome should be, and settled this by observing the flight of vultures as an omen. Romulus won (possibly by cheating); see Plutarch, *Life of Romulus*, 9. 5; Loeb 1: 115. Livy (1. 7. 2; Loeb 1: 25) relates that Romulus then killed Remus and founded Rome; hence Rome's name.

[477] Translating "quidam," not the "quaedam" of 1554 and 1560.

Its plumage along with its skin is adapted as hides,[478] and heat it so much that they burn it. The plumage of the other birds, especially that of swans, is adapted for the same purpose. Vultures can see particularly far away, and seek out lines of battle set out, with a deadly expectation of disaster for the side near which they are on watch.[479] This bird, so well known to the ancients, is still to be seen. But many people have declared that the Phoenix bird belongs more to fable than to the truth, although Ovid[480] wrote:

> There is one bird that renews and reproduces itself: the Assyrians gave the Phoenix its name.

But some people report that in the interior of India there is a bird named the Semenda,[481] which has a beak with a triple rank, and perforated all round as in oil lamps; when about to die, it sings sweetly like the swans, then gathers firewood, ignites it with the movement of its wings, and is burnt up. A worm comes from its ashes, and then from the worm the bird is reborn again. I preferred to include this because of my delicate perception of the tale,[482] which concerns the origin of the globe and of virtue, rather than leave it out because the story of the occurrence mentioned is beyond belief.

But regions differ in both the largeness and the smallness of their birds. With us, surely the goldcrest[483] is the smallest of birds, which flits through the thickets, &770 half the size of a sparrow. But the same India produces the hummingbird,[484]

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478 "pelles."

479 "insederint."

480 *Ovid, Metamorphoses,* 15. 393. The quotation was introduced in the 1560 edition.

481 Mentioned in in Sir Thomas Browne's *Vulgar Errors,* 3. 12, and Alexander Ross (1652) *Arcana Microcosmi,* Book II, Chapter 21, 201–7, as similar to the Phoenix.

482 "subtilem ob historiae sensum."

483 "regulus."

484 *muscatuspasser,* "mosquito sparrow." Andre Thevet, in his *Singularitez de la France antarctique* (Antwerp, 1558, fol. 92), has been more than once cited as the earliest author to mention hummingbirds, which he did under the name of Gouambuch; but it is quite certain that Oviedo, whose *Hystoria general des Indias* was published at Toledo in 1525, preceded him by more than thirty years, with an account of the "paxaro mosquito." Oviedo's account (*West Indies,* 70–71) is still fascinating: "It is as impossible to see its wings as it is those of a beetle or a bumblebee. There is no person who sees it fly but thinks it is a bumblebee . . . one of the birds with its nest weighed only twenty-four grains, feathers and all . . . They are so small that they look like the little birds placed by illuminators in the margins of books of hours. . . . If a man climbs a tree where they are nesting, the bird attacks his eyes and darts away and returns to the attack with incredible speed." The name "mosquito sparrow," though now apparently disused in Spanish, must have been current about that time, for we find Gesner in 1555 (*De avium natura,* 3. 629) translating it literally into Latin as *Passer muscatus,* owing, as he says, his knowledge of the bird to Cardan . . . from whom we learn (*Comment. in Ptolem. de astr. judiciis* [Basel, 1554], 472;

and anyone who has seen this flying would reasonably[485] take it for a hornet or a wasp, since it is so fast and so small. It is embellished with wings that are gold and green and of various other colours; size little larger than a bee; beak as thin as a needle; the whole bird with the nest barely weighs 24 grains of wheat. It creates its nest from mattress stuffing;[486] it is bold, and makes for the eyes of anyone looking for the nest, the more safe for its speed and small size. And so it is agreed that this bird is of very rarefied substance, which makes it hot and bold; since it has a beak, legs, a tongue, wings, entrails, plumage, claws, and a brain, as well as many other items, it should be of subtle substance and well contrived.[487] And I think this is the smallest of all birds. Similarly, the cleverest bird lives in the same India; it is called the "foolish sparrow" from the opposite sense. It is a dark-coloured bird, with fitfully gleaming[488] feathers on its [544]neck; the size of a thrush, which looks after itself against the tailed monkeys (they are incredibly numerous there) in such a way that even a human being could not find so much to help him against danger. Firstly, it selects a tall tree armed with thorns, so that a monkey would be terrified by the height and fended off by the harassment of the thorns. It suspends its very hard nest from the most prickly branches of this tree, so that an enemy cannot break it; it constructs a narrow entrance, to fend off an enemy and let itself in; the nest is wide in its depths, so that it can coexist comfortably with its chicks—particularly because it is bound to gather their excrement in the same place, since no other exit is open except &771 where the entrance is, at the top. But as its enemy knows how to use its hand as a human being does, it stretched the length of the nest to four palms,[489] so that when a hand is put in, it is still far from the bottom, and in that way it protects the eggs or the chicks lying low inside.

As a kind,[490] birds excel to a marvellous extent in their talent and cleverness, because they get fed by fruits, not plants or some worse rubbish, and they live in purer air. And among others there is the parrot, because it has a big head, and is born in a sound climate in India. Thus it has also learnt not only to talk but also to plan.[491] They plan because of ambition for glory—they share in that, and in love, so that they have no ordinary memory. They display great variety in colours,

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see Maclean, *De libris propriis*, M101 [93]) that, on his return to Milan from professionally attending Archbishop Hamilton at Edinburgh, he visited Gesner at Zurich, about the end of the year 1552. From http://encyclopedia.jrank.org/HOR_I25/HUMMEL_JOHANN_NEPOMUK_1778_1837.html, accessed on 23 Feb 2008.

485 "iure."

486 "cottus" or "cottum." The word "cotton" comes from Arabic, not Latin; the Low Latin word "cottum" = mattress.

487 "elaboratus."

488 "intermicantibus."

489 On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

490 "generaliter." This paragraph underwent much expansion in the 1554 edition.

491 "meditari."

so that they are reckoned very pretty among the Indians too; in addition to that neat variety of colours, there is also a sort of shining brightness.[492] This bird is unique in moving the upper part of its beak, but not as often nor obviously as the lower part. The lower part, which is linked to the neck, is split; by these two features the parrot is distinguished from every kind of animal. Thus Caesar Scaliger in part commended it, for moving the upper part, and in part mistakenly compared it to the crocodile.[493]

I would believe that nature could shape no bird more beautiful than our peacock, unless I get to see one with so many eyes in such a long tail thick with plumage, with such a diversity of colours, such a sheen, such well-chosen &772 kinds of colours too, that it admits no matt white (that is one that would dim the other colours) nor dark, since it is rather gloomy.[494] But there are some that are shiny white over their whole body, and very beautiful. They are excellent watchmen for houses, and when they see thieves or a fire, they screech incessantly to warn their master, and the servants too. But at other times they are a nuisance, break roof tiles, and upset the whole neighbourhood with their cries. One was for a long time on view in Greece from the Orient for profit, and had been moved into Europe at Alexander's command. He ordered it to be spared because of its decorative value. It is conscious of its beauty, and cries out while looking at its feet, ignoring their ugliness, and opens up its tail into a wheel, and exposes it to the Sun to make it look more beautiful, and enjoys human admiration from those who look at it, so that it holds its tail up till it is weary. The result is that the Indian peacock marvels at its own tail, longing for it to be turned into a sphere,[495] although it is much inferior to our own peacock in beauty. It is embellished with skin around the head, and can change the colour of this at will. Since it is of diverse colour, marked out (so to speak) with white and gray, with the inrush of blood it becomes now blue and now red. And when it is angry, it displays the look and state of an angry man, provided with that skin instead of a face. But another display is more of one, that it sometimes gathers together that skin, so that it is barely visible, and then it grows pale. Sometimes it distends it, enough to cover the whole beak, and then it looks mostly purple. The evidence then is that it is distended with blood—though I have seen it pale and distended at the same time. So it is gathered in and contracted, since it is &773 thin and loose, like the scrotal skin, which sometimes appears totally contracted and sometimes much extended. Thus looseness and thinness are causes of extension and contraction. But we have spoken of this earlier.

Our cock always has a crest that is prominent and reddish, unless it is in bad health. Even if it were a rare animal, it would richly deserve admiration, not just

[492] The rest of this paragraph appears first in 1560.

[493] "Solus cum crocodilo rostrum movet superius" (Scaliger, *Exercitatio* 236 [735]).

[494] The next five sentences appear first in 1560.

[495] "ipse caudam suam miretur, in orbem conversam gestiens."

for its form but for its song. It runs riot with its voice, which is heard far away, and as far as a thousand paces even at night; it sings when roused from a meal, often with the midday Sun, and at the middle of the night, and when the rays first start to paint the dawn — so it follows the Sun's strength, and divides the whole natural day into eight parts, not with the Sun's rise, but when it reaches the end of the dawn, and thus before midday.[496] It is thought that among northern people, it sticks very precisely to the limit of the hours; people think it keeps them safer from night terrors. They fatten in response to the pleasant odour and the attraction of the heavy taste of juniper.[497] Their intervention in battles and births with a song is a favourable sign, if it is to be portentous.[498] A cock is put into a parricide's sack with a snake, a dog, and a monkey,[499] though innocent of this offence, and is thrown into the sea. A monkey is not a human being, but looks like one — the same is true of a person who kills his own father. A snake forestalls ambushes,[500] and is very hostile to the human race, just as a parricide is. Dogs appear to hate everyone, and this animal is alone in showing mercy to no one, not even of its own kind. The cock, innocent of this crime, is added perhaps because of the similarity of its race, one that the Romans greatly detest, &774 perhaps because it is very disdainful; it is thrown into the sea, as though not worthy of any element,[501] and by association with it air, earth, and water are corrupted; this is why it is sewn into the sack, after a beating with bloodstained rods.

But moving on from these superstitions, let us make our way back to the most sacred and wise laws of nature. It was determined to create birds, which would fly and embellish this air; this example of the birds was chosen as a principle for the other animals, and so they need to have a very light head; hence of all the animals, birds have the smallest head, and those that do have a large one acquire thin bone, bone empty of brain, and large wings. Two drawbacks were consequences of the small head: the one that they were stupid, the other, that they had no teeth; a small head had to have a small beak, and thus teeth of no use, both because there could be no strength in them, and because the small beak and mouth prevented them from being able to chew. [545]The first drawback

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[496] The following three sentences appear first in 1560.

[497] "Saginantur ad odoris suavitatem, et gratiam saporis iuniperi gravis." 1560 reads "granis" here, surely a typographic error.

[498] "prodigiosus."

[499] Juvenal (*Satires*, 8. 213–214; Loeb 341) remarks that for the Emperor Nero's punishment, "more than a single monkey and a single dog and a single snake needed to be provided." For further references to this traditional Roman punishment for parricides, see *OLD* under "culleus."

[500] "insidiis anteit."

[501] "praecipitatur in mare, velut omni indignum elemento." The thought is unclear.

was removed by heat and dryness of temperament.[502] It[503] was also useful for the generation of feathers and for the lightness of the whole body. Then for the whole body to be dry, it wished to be sated by a small drink, and for this reason wished to do without a bladder too.[504] It meets the lack of teeth with a twin stomach, so that hard things are gradually digested in it; since hard things cannot be crushed up, they used to need a longer time and a more solid and tight-fitting stomach, in which a small meal could be contained, one not enough for the body. So another stomach needed to be arranged, &775 in which the food would get half digested, and of a size to contain enough food. Nature also made small legs, because this weight would be of no use for flying, and a sharp gaze, because they would need to see a long way off, and to look down from on high. And if some birds deviate from the pattern, they still do not reach complete use; some people wish shearwaters[505] to have teeth, and such things are required more for diversity than for use. A bat has teeth, but no wings, and the whole of its wings and body are cartilaginous. But when it has come down to earth, it can scarcely make the effort to fly.

All birds are tame almost by nature, and especially those that do not eat flesh; in the New World, when ships had first landed on untilled islands, many birds (especially of the pigeon kind) used to let themselves be caught by hand, and the birds were not afraid of associating with human beings, unless experience taught them to be. Consequently a number of hermits have had tame ones of the kind that are wild, such as sparrows and ravens.

But moving on from birds, let us pass to an animal which lives underground, one of another kind, which is called the mole. It is of an ashen colour, like a mouse in form and size, apart from having no eyes; what good would eyes be to a creature living always underground?[506] And it dislikes the open air so much that if it is made to come out into the light, it very quickly dies. And its tail is different—what is the point of moulding such a long tail when it lives underground?[507] On the same basis too it has very short legs, and very sharp &776 claws; the short legs are needed for making a way through narrow passages, and the sharp claws so as to be able to dig through earth conveniently. This task it performs so fast

[502] Syntax unclear: "Primum incommodum caliditate et siccitate temperamenti sustulit . . ."; I have translated as if "sustulit" were a passive verb.

[503] But it appears that the subject now is the "small head."

[504] Birds have no urinary bladder. The output of the kidneys is released into the lower part of the gastrointestinal tract, so that faeces and kidney output are combined before being discharged.

[505] "Diomedeas"—but Pliny (*Nat. Hist.* 10. 126) says Juba called them "plunger-birds" ("cataractas"), and so perhaps they are gannets.

[506] Cf. sbove at 681 (1560).

[507] Scaliger (*Exercitatio* 244(3) [746]) objects to the argument here, pointing out for instance that horses have tails even where there are no flies.

and copiously that onlookers seeing the earth dug out by a mole for the first time are most impressed. So it is evident that nature has taken marvellous care over all things, and not casually, but has satisfactorily provided for everything, and for the human beings on whom God has lavished this blessing of sharing in that primary nature, so as to discover the primary cause of things—and that the nature which has established these things is not of a different kind from the mind of those who could fully reach their cause, and why they are made like this.

Thus no animal possessing blood and living permanently underground has been found except the mole; some kinds of very damaging snakes and frogs have been found not only underground, and in very ancient tombs, but (and this is more remarkable to report) even inside solid rocks. These, however, are characteristically[508] devoid of blood, and do not bring forth an animal of their own kind, but either eggs or nothing.

There is another creature, of the kind of indeterminate life and unpleasing form, which is defined by the name of crab. There are very many kinds of it—a sea kind, and a river kind. A land kind is also found, which lies low in the earth, especially in the West Indies. The kind that has a tail is called the lobster;[509] it creates shiny white stones in its eyes[510]—shedding its harder shell, it dons a soft one, and then the stones get very large, the matter of the shell being taken up into the stones. The crab walks &777 sideways.

Let that account of the portentous[511] animals suffice. Now we need to know what different and special pulses and breathing patterns[512] occur in individual animals—for instance in dogs and she-goats, what distinguishes them from the human being and from each other. Some organs[513] also retain this type of pulsation after being torn away from the whole (though Aristotle and Galen resist this); for instance, an ox tongue may pulsate a whole day, as the power embodied in it still persists, or because it does it while the celebrated heat is being dissipated. Or for instance air in water puts bottles into motion—even dry pebbles, and burnt horns and bitter aloes in water put bottles into motion, while water is making its way in to replace air.[514] So what we have said about the ox tongue is

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508 "propriè."

509 "Quod caudam habet, gammarus vocatur"; Scaliger (*Exercitatio* 245 [747]) writes, "quod cauda caret, Gammarus vocatur"—"because it lacks a tail, it is called a lobster." The bases of the derivations of both Cardano and Scaliger are not clear.

510 Scaliger (*Exercitatio* 245(1) [748]) denies that stones are formed; the hard things are the eyes themselves, not stones in the eyes.

511 "portentosis."

512 "respirationes."

513 "membra."

514 The thought is unclear, but presumably if a heavy pottery bottle full of air and with a small orifice at its neck is dropped into water and falls on the bottom on its side, the emerging air may propel the bottle along.

remarkable enough, but people say that a veal tongue placed in water also moves, but I have no experience of this yet.

More extraordinary is what Solinus[515] records was still the case in his own time: that no dog nor fly entered the temple of Hercules at Rome.[516] I heard a few years ago that there had been the house of a dumb man at Venice, which flies did not enter; it had burnt down in a general conflagration. But perhaps it was avoided by flies because it was in a lofty position and well ventilated, stiff with iron and marble?—flies dislike all metals, because of their coldness, and because they find it hard to get a grip on them. But another reason needs finding in the case of the dogs, unless there was something buried in the vestibule or hung up that dogs avoid.[517] There is in our town a sacred temple of Faustina,[518] dedicated at one time by the &778 son of St Philip, and now to Nabor and Felix, near the temple of St Ambrosius,[519] which people said no bird entered, though it was open on all sides, with an old roof and wide windows. And though it is overgrown through neglect, it is not fouled by spiders' webs, through the secrets of nature, or more divine causes or deterrents[520]—since Bonaventura Castellioneus (our old friend) recounts this in his little book on the Bishops of Milan and the origin of religion as having been noticed, we have not yet found it untrue. Carthusian monks have often told me that they are not attacked by bedbugs, and this on the evidence of so many people that it embarrasses me to deny what it is flippant to believe.[521] Nevertheless, the monks do not eat flesh, and present that as the reason. I could not find out so far whether it is because of cleanliness or some other technique. But I do not try too hard to discover the reason, having not yet gone into detail on whether it is true.

Now[522] that we have set out what concerns an account of the animals, and are making our way to a discussion of the human being, a problem worthy of debate emerges: what animal is of most use to man? We cannot properly hesitate longer, since in every eye the horse wins; it is extremely well suited for [546] load-carrying. And from a horse and a she-ass, or a mare and a he-ass, mules

[515] For Solinus see n. at 199–200 (1560) in Book II. Solinus (ed. Mommsen, 8) is relaying a tale from Pliny; see n. just below.

[516] This tale about the temple of Hercules in the Cattle Market at Rome is in Pliny (*Nat. Hist.* 10. 79; Loeb 3: 343), where no doubt Solinus found it.

[517] The next two sentences appear first in 1560.

[518] Faustina was the wife of the Roman Emperor Antoninus, who when she died in A.D. 140/1 consecrated her, and she was later commemorated along with him in a temple in the Roman Forum (*OCD*).

[519] The relics of Sts Nabor and Felix, who were martyred in the time of the Roman Emperor Diocletian, rest in Milan, where a church has been erected over their tomb. St. Ambrose extolled their virtues (Migne, *Patrologia Latina*, 15. 1746).

[520] "exemplis."

[521] "quod levitatis est credere."

[522] Material from here to [F] on 789 (1560) first appears in 1554.

are generated, which can carry more than their own weight. They walk with a very steady step. Horses also possess great tameness and docility, two features in which no animal surpasses them. In addition, they have a very tough hoof, &779 all of it immune from harm, and able to accept sandals and iron shoes, and it far surpasses the camel in these respects. It outdoes the other animals at prolonged running, and though a single horse may be defeated by a single camel over a day, more horses arranged at staging posts beat the same number of camels; when a camel is weary, it lets up a little, and an intact and strong one cannot match a galloping or even a trotting[523] horse. So on many scores the horse outdoes the other animals in importance. It is eager for battle, and desirous of glory, and is inflamed by the trumpet's sound, and understands the reins as well as a human being understands a human voice.[524] It is almost always on watch, and does not lie down unless tired or lazy, and it can be fed on cheap fodder, hay, corn husks, herbage, bran, oats. And it alone appears to have been born to provide all human benefits: it carries burdens, it conveys, it runs, it jumps, it fights. It is up to standard[525] in twenty-seven circumstances; that is, three out of each of nine animals taken.[526] The juvenile age of a woman, which in horses extends from the fourth year to the eighth or tenth: tameness and willingness to oblige,[527] so that it does not bite nor kick, it does not plunge into water, it is not stubborn and disobedient, it allows anyone to handle and lead it. Beauty, which (as in the case of women) consists in the face and in breadth of chest and neatness of limbs. The character of an eagle, so that its eye is very lively, it has a small head, and holds it upright. The character of a goose chick or "rosamacha,"[528] so as to be greedy, a fast eater, and despising nothing. It has bulging hips, &780 not narrow, and walks on wide-spaced legs. The character of a lion, to be spirited and courageous, to be proudly erect[529] in front, not hollowed out in the middle, not higher at the back, to be wholly bony and sturdy—these are a lion's characteristics. The character of a stag is to be speedy, a jumper, and light. And that of a donkey is

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523 "velitantem"; this means "fighting like light-armed troops" but is also used to denote a trotting or similar gait of horses; see n. 549 below.

524 The horse's mettle is similarly extolled in Job 39: 19–25.

525 "Probatur."

526 The latter half of this sentence appears first in 1560.

527 "morum comitas."

528 The *corocotta* (mentioned in Pliny, *Nat. Hist.* 8. 107) is the result of cross-breeding a hyena with a lioness. This odd badger-headed, donkey-sized animal whose physique was a combination of stag and lion was able to mimic the voices of men. Its gaze was permanently fixed — probably as a result of possessing, rather awkwardly one would imagine, a rigid spine prohibiting any chance of the thing looking over its shoulder. It had cloven hooves and, in place of teeth, the creature also featured one single bone-like tooth extending right round its jaw. Also called variously . . . *Rosmacha.* See http://www.finestoneminiatures.com/zoo2.htm. accessed on 23 Feb. 2008.

529 "elatus."

to have hard hooves, a hard hide, and a strong back; you will avoid the horse which, while you are climbing up, turns and yields to your weight. And that of a fox is to have a handsome tail; this not only helps its good looks, but indicates strength, because it arises from the vertebrae of the back, and enables it to turn readily in any direction; in this sort of agility, no animal can be the fox's equal, or match the attractiveness of its hide. And that of an ox, so as to have a large foot, and fairly thick legs (thin ones cannot be good), with short firm joints, to let it proceed safely; an ox never stumbles. The special characteristics of a horse are to proceed fast and comfortably, to be alert, and to know how to obey the rein and the spur. A general one for them all, and obvious of itself, is to be healthy; it is a part of its health, and an excellent indication of it, that a horse hardly sweats at its work. Alertness is recognised because it neighs, and cannot keep quiet, and if it is harassed, it champs the bit and strikes its hoof. Hence your poet says: "The horse halts, and fiercely champs the foaming bit."[530]

In history two outstanding horses are recorded: one is that of Alexander the Great, named Bucephalus, either because of having a large head, or a graceful one—the word βοῦς &781 in Greek has both meanings.[531] When it died in India in battle with King Porus, he founded a city called Bucephala, after the horse; the great king either paid such great tribute to the horse's deserts, or showed that he appreciated how much depended on a royal horse. The other was one with human finger-nails, which presaged world power for Julius Caesar, since it belonged to him. It is incredible that it possessed hooves as well as digits, since it could not tolerate a rider.[532] But as was said in the case of the elephant,[533] there were separating lines in the hoof without actual division, creating the appearance of digits. Bucephalus used not to accept anyone on his back except Alexander, less through ferocity than through the ambition inherent in him; thus it was that he commended himself greatly to that most ambitious king.

So when a horse is in the market, look first at its head, which should be small and good-looking, held high, with eyes lively and free of any defect, small straight ears, short ample neck, smart mane, broad chest, with its front part a little higher, back straight and stiff, without sign of scars, spine wider, hips rounded, loins full, tail pleasing, legs straight, and not striking each other as it walks, nor bowed outward, but with firm short joints, a wide foot and quite a thick hoof.

[530] Vergil, *Aen.* 4. 135; for references to the word "sonipes" used by Vergil here as a noun meaning "a horse," see *OLD*. Why "your poet"?—see n. in Book IX at 669 (1560).

[531] Since in Greek βοῦς means an ox, there are large numbers of compound words in which it refers to large size or similar. But it is not clear how the word could relate to gracefulness.

[532] I.e. any other rider (Suetonius, *De vita Caesarum*: *Divus Iulius*, 61; Loeb 1: 83).

[533] In the present Book X, at 704 (1560).

Then examine the teeth, to recognise the horse's age, and squeeze its throat—it will take this amiss if it has poor wind. Presently, pull the tail—if it gives way, it is feeble;[534] then squeeze the individual joints, especially those adjoining the feet, and turn them inward a little; if it is in pain, it refuses to stay still, and is suffering some earlier &782 disease. Consider its colour too: the best one is light,[535] since it indicates a horse that is noble and well cared for. Of the others, the dusky weasel colour is good, which in their mother tongue people call "bay."[536] Then mount, and you will see whether it shrinks from its rider, whether it humps[537] its back— these are very bad features. Then turn it round to each side, and you will see whether it is good at turning. Make it move—you will notice whether its pace is agreeable, and its speed, and the kind of gait. Try galloping: when it is pulled back how it obeys the bit and reins; how it obeys the spurs while galloping. Then you will appreciate how light it is, how swift, how safe, how its wind is heavy or easy.

Then take it to water; you will recognise whether it throws itself in of its own accord.[538] Allow it to drink—if it sinks its whole nose in as well as its mouth, especially after a race, it is sound in chest and wind. Also take it near rotating wheels; if it approaches reluctantly, it is nervous; if it does not wish to, it is wholly stubborn. In the mother tongue they call this "jibbing."[539] Next, offer it food; if it eats with enthusiasm, good; if slowly, it is either sluggish or fussy.[540] Meantime, if oats have been offered,[541] it becomes very clear whether it is inclined to kick[542] or to bite. If it lies down when the oats have been removed, it is sluggish and slow to start work; a noble horse does not lie down except after great labour. While it is fitted with bridle, reins, [547]saddle cloths,[543] if it whinnies, if it chews the bit, especially if it foams, if it strikes the ground with its hoof and pricks up its ears, it is fierce and lively. Make it jump—you will discern its lightness, and the strength of its back.

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[534] Is it the tail or the horse that is feeble? The Latin does not resolve this issue.

[535] "optimus enim est qui splendet." 1554 instead recommends a white star on the horse's forehead, and includes slightly different advice on colour.

[536] The horse colour "bay" in English is derived from the Latin word "badius" (not "baius" as here) which denotes a horse colour either bay or chestnut, and may be linked to an Old Irish form "buide," meaning "yellow" (*Chambers Dictionary*). But the "baius" here is surely the ancestor of modern Italian "baio," a bay horse.

[537] "sinuetur."

[538] "agnosces an se ultrò in aquam iactet."

[539] "restium"; the word for "jibbing" in modern Italian is "restio."

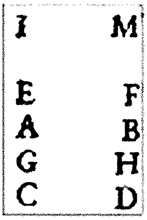
[540] "gulosus."

[541] The Latin contains no indication of any perceptible delay between the offer and the recalcitrant behaviour, such as might occur in the phenomenon of a horse "heating up."

[542] "calcitrosus."

[543] "ephippiis."

In our books *De Rerum Varietate*,[544] we have discussed &c783 diseases and their treatment. But now is the time to set our hand to what is of the utmost utility, the reason for this discussion,[545] since it is a subject for delicate[546] consideration. It is the subject[547] of the different ways of sitting a horse in relation to speed and convenience. There are three points in how to produce speedy progression. The first is for the horse to move its legs fast, and thus its run[548] is faster than



"velitatio."[549] The second is for it to move two feet at a time, not just one; with two feet moving at once, the horse moves in a paired movement, but if it only moves one, it requires four movements to make progress. So "velitatio" and "gradarius" are faster than simple progression.[550] The third is, that its feet should cover a wide interval, when during progression the leg rotates at its joint as an axis. In this, people notice particularly the rear feet,[551] because if their footprints are ahead of those of the front feet, the horse must make more headway[552] through the motion of two feet—the back and the front one—than the gap between the back and the front foot.

Everyone knows that this is the major cause of fast progression: let us suppose that the horse's front feet are AB and the hind ones CD, and that A is moved away and C is put in its place; when B is moved, D will be put in its place; so the horse progresses from CD to AB, and thus progresses the distance that its hind feet are from its front ones.

But when A is moved away, if C is placed at E, then when B is moved away, D will be placed at F—the horse will progress from CD to EF, &c784 a larger distance than that between the front and the hind feet—but this only occurs with difficulty. However, if C is placed only at G, and D at H, it is reasonable that this gait[553] should be common to almost all horses.[554] And it is obvious and clearer than

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544 *On the Variety of Things.* See n. to the Dedication of the 1550 edition, preceding Book I.

545 "sermo."

546 "subtilis."

547 "tractatio."

548 "cursus."

549 The word "velitatio" is also used on 779 (1560) and there too is clearly a horse gait such as trot.

550 These gaits evidently involve moving two feet at at time, but it is not easy confidently to match the gaits named by Cardano with those nowadays recognised. I am grateful to Dr Anne T. Lambie of Edinburgh for experienced advice on the ways in which horses progress.

551 "observant," not "observantur," so I translate accordingly.

552 "progrediatur."

553 "incessus."

554 Just how a horse proceeds at various speeds was mainly settled by the photographic studies of Eadweard Muybridge, an Anglo-American who published his 11-volume work

light that if C is placed at E, and D at F, and A at L, and B at M, then L is as far from A and M from B as E is from C and F from D. Otherwise, if they are more or less, C and D will gradually approach A and B, or be moved apart from them so far that the horse will fall—as we never see this happen for that reason, it is certain that the front feet always move equally with the hind ones. However, it is not easy to see that the progress of the front feet equals that of the hind ones, because their footprints are more confused. And for people ignorant of it, it is not easy to conclude that the hind feet always move equally with the front ones, because when the front ones make much progress, the horse moves fast. This is why the progression of horses is normally measured by the motion of the hind feet, not the front ones, although the principle is one and the same. Another point worth noting is that if you look straight, it is not just horses but all the other animals that naturally move their right front foot first, then the left hind one, then the left front one, and the right hind one; if the two front ones were to move simultaneously, for instance from AB to EF, then the animal would get stretched out from CD to EF; that would inconvenience its natural progression. If the right rear one were to follow the right front one, and this occurs at the same time, the animal is &785 twisted apart and has nothing to support it; so it is more convenient for the left hind foot to follow the right front one; in this way the animal is supported meantime on the right hind one and the left front one. Human beings find that this motion suits them, in which one part is at rest while another is in motion; when a human being moves both feet at the same time, he has to be unsettled as though jumping; in walking and running, one foot is always at rest while the other moves. So if the whole human being is raised up, the whole has to fall down too, and so is shaken up. And if someone jumps persistently all day long, is he not noticed as having all his entrails disrupted? And if the same thing happens to a horse, just the same happens to his rider too, except that his feet will not hurt, because the rider does not rest on his own feet, but on the saddle cloths and the horse. So a horse cannot move four feet at the same time;[555] in jumping, a human being has to bend his knees, but a horse does not bend its knees before it is up in the air, so a horse cannot move four feet at once. But it is absurd that it cannot actually move three either—so it either moves one, or it moves two feet at once. In accord with this theory, eight kinds of movement by horses emerge: three of one foot, and five of two. Thus when it moves the right front foot first, then the left hind one, or the right one too—we see this happen too in some of them, and there is not much progress—it is called simple progression, gentle and slow—slow, because it is with one foot, and that foot covered little ground; gentle, because the person &786 riding it is moved on one side

in 1887 with 100,000 photographic plates. There are in fact six possible sequences in quadrupedal locomotion; for details see T.A. McMahon, *Muscles, Reflexes and Locomotion* (Princeton: Princeton University Press, 1984), 171.

[555] This is not true, but no doubt the truth was difficult to discern until the photographic studies of a very much later epoch.

only: right and left alternately. This progression is more convenient for horses, and tires the horse on neither side, since it is in accord with nature. But when a hind foot almost matches the position of the front one, and foot follows foot quickly, it is called "Propassus," that is, greater progression.[556] This is convenient, and through it many horses strike the hind feet with the front ones, as "twisters"[557] do. Thus horses strike their feet when they are slow, and cover a greater interval through the motion of their feet.

But when the right front foot is moved, if the right hind one, not the left one, follows on quickly, the gait is gentle, what the common people call the "traina";[558] it is characteristic of mules, and does not tire the rider[559]—indeed, at equal speed, less so than the "propassus," because only the right side moves, then the left side. But the "propassus," by linking the left hind to the right front and the right hind to the left front, when it is fast appears to move all the rider at once , and therefore shakes him up too.[560] But whenever two feet move at once, or two on the same side, for example two right ones, then left ones—some people call this the "gradarius," and it is the gait of the Asturian horses; of all the horse gaits,[561] this is surely the most distinguished, being fast, because it [548]happens with two feet at once, and faster too so far as the feet move more nimbly and cover a larger interval. And it is pleasing, because while one side is in motion the other is at rest. This is the well-known and very celebrated &787 mode of progress, which the common people call the amble.[562]

But if the right front moves with the left hind, it is the gait of twisted horses,[563] and since it moves both sides of the horse, it moves all of the rider too, and shakes him up—and the more so the higher the feet get raised from the ground; it is always the case that horses that raise their feet higher as they proceed make riding harder, though less dangerous, because the feet stumble

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556 This gait is now known as the "fast walk."

557 "multi tamen equi ob hoc, velut et tortores, pedes posteriores allidunt anterioribus." Probably a type of horse that behaves in a special troublesome way; on this see the reference to "twisted horses" at 787 (1560).

558 In Italian, "traina" still means "a kind of broken trot."

559 "hominem."

560 The rider could smooth his own trajectory as the horse rose up and down by rising in the stirrups; these had been introduced to Europe from China in the 8th century A.D. (C. Chevenix Trench, *History of Horsemanship* [London: Doubleday, 1990], 64–65).

561 This is the gait known as the "pace," and pacing races occur in which it is obligatory.

562 "portans"; the Chinese taught this to their horses, and it is "extremely comfortable for riders of riper years, ample dignity, and embonpoint. Unfortunately, it is very hard on the horse . . . and most horsemen, in most parts of the world, condemn it" (Chenevix Trench, *History of Horsemanship*, 67 and 174).

563 "Quòd si simul dexter anterior cum posteriore sinistro moveatur, tortorum equorum hic est incessus."

through being struck by stones. But if the front feet move together, then the hind ones together, in fact not extremely quickly, but it has to be quickly, this gait is the "velitus," this is the flight;[564] if very fast, it is the run.[565] Both these shake up and tire the rider, but less so than that of the twister,[566] because the hind or the front part of the rider is at rest, but more so than that of the Asturian horse, because for it rest of a part is not natural; in fact the rider moves his front part first, then the hind one, but the right one before the left, or anyway vice versa. However, if the hind feet get raised when the front ones are not yet at rest, there is a jump. There are thus three distinguishing features of times:[567] the first,[568] in which the front part of the horse is raised while the hind part is at rest, shakes up the rider very little, as I said, because the hind part is at rest. The second, in which with the front feet not yet at rest the back ones are raised; this does not produce shaking, but the bending tires the &788 kidneys because of the reversal of movement. The third, in which all the feet come down at once, or the front ones first; if in fact all the feet come down at once, the rider is much shaken, since this occurs from a height. If just the front ones come down first, the stomach is much disturbed because of the slope.

So this is the account of horse motion. But their aptness to learn is also extraordinary, so great that some of them grab a sword coming down with their teeth, and present it to their master, as an elephant does. Others—a lesser feat—bend their knees. As was said about dogs, they are trained when young by starving them, then by attaching bread or hay to a sword, and while they are keen to tear off the hay, the trainers lift up the sword, pull off its hilt, and enable easy access to the food. They also smear the sword with honey, so that the animals are happy to seize it.

Then when the habit has been developed (the same persistence has stood me in good stead too while breaking horses), the animals seize the naked sword of their own accord with their incisor teeth; horses remember what has suited them and what has not. Thus there is no better way to correct a horse that spontaneously plunges into water than for two sturdy men to grab its ears when it is already immersed, and hold it under till it nearly drowns. After that, it recalls the danger and the stress, and does not dare to imperil itself again. The same applies for a horse that resists and refuses to advance; it is pulled back willy-nilly till it gets into fire or thorns, and is not allowed to advance till it has reached extreme danger to its life. And if it rears up, its head is run through with spikes and it is

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[564] "velitum hic est incessus, haec est fuga." Confusing.

[565] "cursus"—probably the gallop.

[566] "Hi ambo hominem concutiunt et fatigant, minus quidem quàm tortoris, quia pars posterior . . ."

[567] I.e. the stages of the jump.

[568] Translating "quidem," not the "quidam" of 1560.

not allowed to come down again. Other people beat its &789 head with a club, which achieves a good deal.

[F] Much has been said and in detail about animals, and let this be enough, about what arms individual ones against lack of food and drink, and to preserve the fetus and offspring, against diseases, against harm from the passage of time, against other animals, and finally with a special interest against human beings, which was to be the cleverest. Firstly, against lack of food, the protection is by galloping, shrewdness, and also by being born where there was a good supply. Sexual pleasure and love of offspring towards the preservation of the race, marshes, waters, mountains, valleys, caves, hiding places, woods, thickets, boughs, branches—all these to protect the young. And nature taught herbs for health, and abstemiousness, and repose—more than to humanity, because of the inexperience of physicians—assistance from the resources of medical skill. Against weather disasters: trees, mountains, pits, hide, wool, hair, plumage. Against other animals: prickles, teeth, running, jumping, wings, claws, hiding places, venom, waters, cunning, horns.

Nature armed fishes against human beings with their element, which is the most complete protection, so that unless their greed misleads them, they can lie low in whirlpools in safety. It armed snakes with a low-lying body, which enables them too to lie low in winter in hiding places—when they emerge, they are hidden by the grass. For the day, nature has provided the birds with wings, and the quadrupeds with speed; for the night man has been made unable to see without a lamp, though all the quadrupeds can see—the dogs, the wolves, the hares, the horses, the donkeys, the oxen—and consequently can range in safety and enjoy food and drink, since by day human beings are in possession of all the opportunities.[569] But because light was denied to &790 birds by night too, treetops and tower tops and thorn bushes provided a bed, to let them be safe from human snares through the inaccessibility and dim light of the place. An addition to this provision for all animals is something useful to man, since he could use light during the night, for since he was going to be extremely wise, a very moist and cool brain was necessary;[570] he should have a very hot heart, so that a very soft body would be equal to hard work—but a very soft body was required so that a very thin matter would exist and be suitable for a spirit able to deal with such great challenges. And so—to proceed from the start to the conclusion—it was totally impossible to locate glittering dry eyes (such as cats and nocturnal birds that have a very dry brain possess) in a very moist and cold brain. Hence I will now set about starting the account of the necessity and fortune of the human being.

569 "saltus."

570 Scaliger (*Exercitatio* 248 [759]) comments that Cardano should have recognised that a fish's brain must be much cooler still!

[549] &790 Book XI
On the Necessity and Form of Man

It will be necessary first to specify on what account everything has been created, and whether everything is for the sake of man alone, and whether man is an animal. Therefore what should make the start of the discussion is whether man is an animal.[1] Next, whether the animals themselves are known &791 to nature by their kind alone, whether the parts too are known, and also the details themselves; this even in the case of man is open to greater doubt. Furthermore, whether the animals themselves and the plants and the other things exist on their own account or on account of man—and if they exist on account of man, whether immediately on account of man, or whether these are on account of other things in some sequence—herbage for instance on account of hares, but hares on account of foxes, and foxes on account of the convenience of man; there never has been found in the past a more beautiful or more difficult discussion than this. There is actually huge uncertainty over why there are not more kinds of animals than these, if nature tried to fulfil whatever it could achieve—or why it was satisfied with these entirely on their own. It is usual to meet this uncertainty in many ways. And goodness, Epicurus meets it nicely when he says that nature did what it could, but all that had remained was what possessed some outstanding power for protecting itself. This is what he actually says:

> Many were the monsters also that the earth then tried to make, springing up with wondrous appearance and frame: the hermaphrodite, between man and woman, yet neither different from both.[2]

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[1] In 1550, the question whether man is an animal is not raised in this sentence nor the preceding one. 1550 continues: "Hoc igitur initium disputationis efficere oportet, vtrum ne animalia ipsa genere solo naturae cognita sint, an partes etiam, an etiam ipsa singularia, quod etiam in homine maiorem habet dubitationi."

[2] Lucretius, *De rerum natura*, 5. 837–839; Loeb 401. While Lucretius is the author, he is representing an Epicurean viewpoint, and so Cardano names Epicurus as the speaker.

Then he also adds:

> For whatever you see feeding on the breath of life, either cunning or courage or at least quickness must have guarded and kept that kind from its earliest existence, maintains it, and we have much that serves us well, which remains approved, handed down to us for our protection.[3]

Then a little later:

> But the things to which nature granted none of these, could not live either &792 of their own accord, and these used to be brought low.[4]

Finally he appends:

> Shackled all in their gruesome fetters till nature brought down that kind to destruction.[5]

No[6] small advantage follows from this opinion of Epicurus: that is, that it is possible to assign a cause for monster-bearing forms: that nature often initiates species of animals, and being then unable to maintain them, they are reckoned as monsters. But he himself errs in two ways: first, because there is still remaining doubt, since other animal forms could have been created which would have persisted, such as wolves with horns, and dogs with sharp claws. Next, because he wants nature to have set up everything by chance—horror! So it seems to me that one of two alternatives must be the case: either that the forms of living things are established by the number and powers of certain stars, or that they continually change with the succession of the seasons. The evidence is their diversity in regions, some regions and other ones, as was described above, and in seasons as well. When the details are scrutinised, it is accepted that not all of these forms have been created for the sake of man or of other animals, since many

[3] Lucretius, *De rerum natura*, 5. 857–861; Loeb 401.

[4] Lucretius, *De rerum natura*, 5. 871–875, but text in fact runs: "at quis nil horum tribuit natura, nec ipsa / sponte sua possent ut vivere *nec dare nobis / utilitatem aliquam, quare pateremur eorum / praesidio nostro pasci genus esseque tutum, / scilicet haec aliis praedas lucroque iacebant* . . ." and Cardano's text has omitted the words italicised, and inserted "hae ipsa" before "iacebant." Translation (Loeb, 403; the portion referred to in n. 5 below is included here) runs: "But those to which nature gives no such qualities, so that they could neither live by themselves at their own will nor give us some usefulness for which we might suffer them to feed under our protection and be safe, these certainly lay at the mercy of others for prey and profit, being all hampered by their own fateful chains, until nature brought that race to destruction."

[5] Lucretius, *De rerum natura*, 5. 876–877.

[6] This sentence first appears in 1560.

moles[7] live and die for themselves. And not the forms of the majority, or those of the species alone, provided they appear made for the sake of other animals. Thus the actual species of things are made either for themselves, or for the sake of man. It is totally mad to say that so many kinds of snake that are deadly to man (and their lethal venoms) are created for man's sake.

What more is there to say? There have been a number of craftsmen, and each &793 made provision for the advantage of his own handwork.[8] So the one that made provision for man constructed him in such a way that he would be very intelligent, and could make sound use of all the others, or anyway avoid those that could be of no use. Thus the craftsman who made provision for eagles was wiser than the one that made provision for cuckoos, and yet each one made provision for the permanence of what he created. So when nature had created man, in such a way that he could use all the others conveniently, man seemed created so that everything looked created on his account. But that is not how it is; everything is actually created for itself, and the quail is not created less on account of the hawk than the animals are created on account of man. Therefore things that are generated at a worse level[9] look as though made for the sake of the better ones—but they were not.[10]

And so out of this the solution to another problem emerges: why among the animals are there some that are (and are seen as) unfortunate, such as hares, frogs, chamois? Hence the poet[11] used to say: "We unwarlike does—what are we but prey?" They would be fortunate enough in their own nature, but the wisdom of other craftsmen stands in their way; so they are all known, but according to their species. There is serious uncertainty about the outstanding details in the human species alone; what I call outstanding details are those whose power

7 I.e. the burrowing animals.

8 "Unusquisque commodo prospexit sui opificii." The task here is the work of God, and yet the "craftsmen" are plural. But in *De Subtilitate* mention of gods in the plural is not uncommon; see, for examples, Books X at 713 (1560) and XIII at 882 (1560). The classic treatment of the background to this apparent (and possibly heretical) inconsistency is E. Wind, *Pagan Mysteries in the Renaissance* (Harmondsworth: Penguin, 1967), esp. chap. 13, "Pan and Proteus"; Wind traces a relationship, for instance, between Venus and the three Graces, and notes the three goddesses who competed for the sanction of Paris. For a consideration of "polytheism" in Renaissance epic, to which it was especially suited, see Tobias Gregory, *From Many Gods to One: Divine Action in Renaissance Epic* (Chicago: University of Chicago Press, 2006). J. Hillman, *Re-visioning Psychology* (New York: Harper & Row, 1975) (esp. 139–40 and section 4 of the whole work) devotes some attention to psychological aspects of "polytheism" in the Renaissance. See also C. Trinkaus, "Paganism," in *Encyclopaedia of the Renaissance*, 4: 362–64.

9 "conditio."

10 "falsò."

11 "ille"; he is Martial (*Epigrams*, 13.94; Loeb 3: 211), "Imbelles dam(m)ae, quid nisi praeda sumus?" Robert Burton (*Anatomy of Melancholy*, 863) quotes this sentiment.

is exerted in many cases, particularly kings and wise men. And so the utmost wisdom of such a great craftsman is evident to me in two points: that nothing should be left unused in such a large mass, but everything should either be alive or be food for things that are alive; and that out of this so foul deposit, nature should form something capable of ruling all these lower creatures, and capable of being like those supreme separate substances. It used to appear that he would &794 have to possess a knowledge of everything; and so he provided as large a share of sensation, memory, and prudence as it was possible to lodge in such crude matter. And since those above excelled mortals in five fields—wisdom, happiness, integrity, length of life, and freedom from anxiety—he was unable to provide a mortal with freedom from anxiety,[550] but bestowed the rest so far as he could. Since matter is fragile and undeveloped,[12] it needed much help. Heat was required, so that it would be thin and adequate for movements; and thinness for ability, solidity for long life, temperament for charm and restraint of behaviour. Anyone can see that these things are incompatible in two ways. But very complete assembling[13] was providing everything. However, almost endless obstacles were in existence to its turning out very complete. Thus it came about that in place of brave men, most were nervous, timid instead of restrained, greedy instead of economical, prodigal instead of liberal, cruel instead of strict, wanton instead of pleasing, and in the end many turned out crazy, deranged, and—in a word—unsound.[14] It is the same with endowments of the body as it is with endowments of the mind: many are born crippled, weak, sickly, loathsome, foul, unwarlike, short-lived. And human beings were not created on account of one or other of these, but on account of the most perfect specimens, and the whole species of humankind, which includes all the assets granted to it. We do not cultivate trees themselves on account of eroded fruit, rotten and unripe, and dropping of itself through some defect; likewise, nature does not interest itself in us because of the unsound, but in fruit because of the perfect fruit, in a tree because of the very best ones. It has therefore left &795 traces of its original heavenly matter in these lower creations, since it had separated this mortal matter from it at the start. It should not be blamed for failing to desert the best on account of the bad specimens, or for failing to present to us things repugnant to mortal nature. It has, then, provided everything with some soul, and has created living and sentient and in the end intelligent things with a better one so far as it could.[15] And so it presented humanity with everything. Then in these cases it moved on in a fixed sequence from the most imperfect ones to the most perfect ones, so far as each sort of matter permitted. The start was therefore from

[12] "rudis."

[13] "compositio."

[14] "improbus."

[15] The syntax is contorted and the translation has extracted the most credible interpretation it could.

the metallics, as being prematurely made parts, then the metals, the stones, the plants, the marine creatures, sponges, sea anemones and shellfish, worms, ants, mosquitoes; fish, birds, hares, dogs, elephants, long-tailed monkeys, and finally man was created.[16]

You ask, "What good really is a fly?"—to mention a very worthless and unfamiliar animal. My reply is that the animal itself, while it stays in its species,[17] is on its own, and embellishes the world, and has secured everything it requires, not just for life, but for a happy life—it has been made on account of itself, not to be an enemy to man; not every fly is an enemy to man, but some stay permanently in woods; and in some parts there are none, as among the Lapps, and there are also few in the West Indies. Consequently the general good should take precedence over the inconvenience of the few. So divine wisdom in each case made the best result that could be devised from such matter. Many hares are unfortunate, but not all; &796 some have never seen a human being, or a dog, or been hunted. With a species and the animals themselves, the position is similar to that with a human being and his parts. Who is mad enough to refuse the loss of some members, rather than perish? Animal members are related to the species in this way, that it is far better to perish while the species remains intact, than for the species itself either to be abolished, or never established. However, what is much better in the case of the species, is what is so well preserved in the very scarcest animals, as in the most numerous, and absolutely no function perishes.[18] If an animal's limb perishes, the function[19] perishes too, and the animal is rendered lame or blind, and still prefers to stay alive, even when moribund.[20] How much more is this true in the case of a species that is not deficient in any of its functions, nor deformed, and has attained immortality,[21] even though located in the scarcest animals!

So to enable a human being to attain every convenience, he is ultimately derived from broken-down[22] elements; plants are the first to feed on the elements, animals feed on the plants, human beings feed on the animals. This is

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16 On this progression see A.O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (New York: Harper & Row, 1936). He displays on a vast canvas the twin doctrines of plenitude (that God has made everything that possibly could exist) and continuity (there are no gaps between one item and the next) in a theoretically perfect world. See W.F. Bynum, "The Great Chain of Being after Forty Years: An Appraisal," *History of Science* 13 (1975): 1–28.

17 "ut specie ipsa manet."

18 "operatio"—this is obscure, but the next sentence does seem to indicate this meaning for this word.

19 "operatio."

20 Inserting a colon here, with 1559.

21 In the sense of the ability to perpetually propagate itself as a species.

22 "refractis."

why all the carnivores are more keen-scented[23] than creatures that do not eat flesh, and quadrupeds and birds are more keen-scented than fishes,[24] through two causes: first, because they have food that tries to escape;[25] it has to be discovered and pursued, while discovering it is enough for the rest. The other cause is that the food itself (I mean flesh) is derived from blunted[26] elements. Therefore no flesh is very hot, as[27] can often be seen in plant seeds and parts of plants.

And so a human being, who also feeds on flesh, especially that of birds,[28] &797 could be simultaneously of a very thinned-out[29] and compact, a very hot and a very temperate nature; insofar as he has a great deal of air and heat, and the cold elements in him (earth and water particularly) have departed from their special nature, he is very hot. But as nothing is more thoroughly concocted than it should be, and he comprises very little and very pure earthy element, he is extremely temperate. Hence when a human being is destroyed, he leaves barely five or six ounces of pure earth.

And[30] this appears credible, for a human being is an animal, and up to now this has been believed. But a human being is no more an animal than an animal is a plant; if an animal is not entitled to the title of a plant, even though it is nourished and alive, it is not a plant at all, because unlike a plant it has a soul that feels; since unlike an animal, a human being has a mind, he stops being an animal; as Aristotle bears witness, he has a different kind of soul, because he can feel and understand.[31] If in fact a form differs from another one, the one cannot be included under the other. A human being manifestly feels as a living animal does, but a human being is not an animal, as an animal is not a plant. If in fact a human being is an animal (that is, the animal of which his final form is the soul that brings sensation about), it will be obvious on the same basis that he is

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[23] "sagax."

[24] This appears to be the meaning of "inter pisces, quadrupedia et aves sunt sagaciora" here.

[25] "fugacem."

[26] "retusis."

[27] Or, "though (heat) can often be seen . . .," but the Latin runs, "ut licet conspicere . . ."

[28] "volatilium," "volatilis" being the origin of the French word "volaille" ("chicken").

[29] "tenuissimus."

[30] This paragraph first appears in 1554.

[31] That animals lack a soul like the human one is discussed by Aristotle chiefly in his *De Anima*, trans. R.D. Hicks (Cambridge: Cambridge University Press, 1907): "Mind in the sense of intelligence would not seem to be present in all animals alike, nor even in all men" (1.2.5; 404b5–6), "No brute is ever convinced, though many have imagination" (3.3.8; 428a22), "In the animals other than man, there is no process of thinking or reasoning, but solely imagination" (3.10.1; 433a11–12). On this issue see esp. Richard Sorabji, *Animal Minds and Human Morals: The Origins of the Western Debate* (London: Duckworth, 1993), esp. 9–36.

a plant too—but no one accepts that, no one believes it. And the basis on which the power of sensation is included in a human being is just the same as that on which it is living in an animal. But it is not an animal only because it is alive; that is a plant, similarly a human being is not an animal. Finally, if a human being is an animal, is he one that employs reason or one devoid of it? He is not devoid of it—&798 that would make him a beast. So he does employ reason. And so the use of reason is a distinguishing feature of the animals (like the distinguishing feature of an ox, for instance, or a hare). Hence a soul that can feel is capable of using or not using reason; an intellect is located in it. It is really clear that any distinguishing feature can exist in the being to which it belongs.[32] [551]Could the power of sensation be able to understand? Thus a human being is endowed with life and the power of sensation; it is ludicrous to call him an animal or a plant. There are people who have felt that a human being was an animal, because of the concord[33] of nature in diseases of the soul and body, and because some diseases are transmitted from animals to human beings, such as vitiligo,[34] which from horses (especially white vitiligo) passes across into human beings by touch alone, so that anyone who has dealt with a horse which is affected by a disease of this kind is at once attacked by the disease. There are also things that pass from plants into animals, so that[35] it must not be said that animals are plants. And so let us move on to discussion of the human being.

The human being is created for four roles: first, to acquire knowledge of divine things; second, to be the link bonding mortal things to them; third, to be in authority over mortals; something excellent and very important was essential in this kind, just as in the heavenly kind, to keep control over the rest, in one direction by force and in the other by consent. Fourth, so that whatever mind could devise would be provided all of it by the great craftsman through thought alone, and an animal would be deceitful—the beasts could not be deceitful, being stupid, nor the higher animals, having integrity.[36] This is not actually the &799 aim,[37] as that is a good thing, but it is necessarily linked to the aim. This is a situation to avoid, like death; there are some things needing to be avoided, being evil, although they concern the embellishment of the universe—and if

[32] "Perspicuum enim est, differentiam quamlibet in eo esse posse, cuius est differentia." Obscure. Cardano might possibly mean that a distinguishing feature must lie between the two or more items that it distinguishes, and not in either.

[33] "consensus."

[34] This is probably ringworm (tinea), which is transmissible from horses and may produce silvery scaling. Vitiligo as described by Celsus (5. 28. 19) is evidently what is now called psoriasis; his includes two white forms and a dark one. Celsus says nothing about transmission from horses, and psoriasis is not a transmissible disorder.

[35] "quamobrem"—but the sense is much better if "yet" replaces "so that."

[36] The next two sentences appear first in 1560.

[37] "finis."

they are not totally abolished, like birthmarks and flies, and everything that seems to be for the sake of the whole and not of a single part. So a human being is made like the gods by his intelligence, and like the beasts by his depravity. Thus humankind is threefold: the divine, which does not mislead nor get misled; the human, which does mislead and does not get misled; and the beastly, which does not mislead, and is misled. What misleads and is misled, and what alone makes up the largest part of the human kind, is not a simple item,[38] but a mixture of the beastly and the human kind.

I shall now mention the way in which nations and provinces, also kings and wise men, are known while the primary principles are on guard. At the start I pass over what we showed in the book *De animorum immortalitate*;[39] I mean that each detail gets known by assembling options through many general aspects;[40] this is not to know them for the first time, but on some other basis; however, I now set about explaining that kingdoms and peoples, then kings and wise men, are known on their own, and much better than corrupt and private and undistinguished people. The whole human race is known, and also all the land that is habitable; any selected part of it is definite, such as a hundredth or a thousandth, and likewise the nation that inhabits it is known, so that some portion of the whole human race is definite. But the kings and armies and wise men are the cause of these, and for &800 provinces either perishing or flourishing in prolonged felicity. And so these causes should be known, not in isolation[41] but in how they relate to provinces, kingdoms and cities. They are therefore known, and signs and wonders have regularly attended their birth and decease;[42] a great deal of care was therefore taken over them. In kind, he is created nude, so that he was more beautiful, slender and moist.[43] But since nakedness is at risk from perils and is insecure, he was armed with three defences: with talent to invent what was needed; with speech to obtain assistance; with hands for the completing of all he had devised with his talent or learnt from others by speech. No other animal can really talk, since words do not start out from the mind, nor have hands, but something like hands. And so he starts by using his reason to find essentials:

[38] "modus."

[39] *On the Immortality of Minds*. First published in 1545; for details see Maclean, *De Libris Propriis*, M55, 73–74.

[40] "contractis per multa generalia conditionibus."

[41] "simpliciter."

[42] Marin Mersenne (*Quaestiones in Genesim*, cap. 1, versiculus 1 [401–2]) takes exception to this passage, and indeed to book XI as a whole, in his view so erroneous that a whole book would be needed to cover the objections; he suspects Cardano of atheism, and he endorses Scaliger's *Exercitationes*, 250–69. Ordinary people are as well known to God as their "betters."

[43] "In genere verò nudus creatus est . . ." It is not evident what the subject is. The human being? It seems so, as in Genesis 3: 7, 10–11.

home, clothing, weapons, food; then to measure out land and seas; and not satisfied with these, by planispheres, gnomons,[44] and armillary sphere he summoned down to earth the wide mass of heaven, barely conceivable by the mind, and shrinking and narrowing it he placed it before his eyes and senses. Thus he established natural philosophy, and the other sciences; lastly he turned his mind to laws with which the multitude could live. Human beings in fact used to differ from each other, and also now do so as much as beasts differ from human beings, in law, language, provinces, ways of life. A Christian is not worth more than a rascally and valueless dog among the worshippers of Mohammed, nor a Jew among either of these; he is laughed to scorn, kicked, beaten, robbed, and &801 ultimately killed; he is driven into slavery, assailed by foul and rough insults and ill treatment, worse than he would suffer from a tigress whose cubs he had carried off. There are four laws: those of the Idols, the Jews, the Christians, and the Mohammedans.

The idol-worshipper prefers his law, on four lines of argument. The first is that he has ended superior to the Jews in battle so many times, till he made an end of that law. Hence he believes that to the supreme craftsman and ruler the worship of many gods is as pleasing as that of one, the supreme craftsman and ruler. Next, because in a population with some supreme ruler, it is more appropriate for anyone to resort in private cases to the ruler's officers and courtiers (especially the most minor ones) than to disturb the king himself with every case. Similarly, as this supreme God has minimal concern with these low-grade people, but the business of private persons secures a tiny share of these low-grade people, they assume it is more opportune for the servants of that supreme ruler to have recourse to the gods in connection with any unimportant business, than in such lowly cases to torment with their prayers him whom it is wrong to try to emulate, even in thought. In conclusion: by this law and these instances, while they hope to escape from mortality to divine worship, it appears that very many famous virtues have emerged, such as Hercules, Apollo, Jupiter, Mercury, Ceres.[45] So far as miracles are concerned, it appears that in their cases no fewer instances of divine assistance from their gods appeared, nor fewer oracles than in all the other faiths; and our view about God and the world's origin is no less absurd, indeed far more absurd than theirs, &802 as is clear elsewhere from the conflict between the laws themselves, and from their detestation of all philosophers as authorities for the truth.

But they raise objection to human victims, to reverence of silent statues, to the multitude of gods which are derided even by their own worshippers; and to their own unspeakable crimes too, which anyone would be ashamed even to consider, and to the unwelcome heedlessness of the supreme craftsman.

[44] "scioterica."

[45] The significance of the hero, three gods, and one goddess here is unclear.

[552]With this reversed, the Jew rises up against the Christians: "If there are any fables embodied in our law, they have all passed across to you, who are recipients of our law. No one worships the simplicity of the one God as sincerely as we do, and this worship's beginning was our doing: greater miracles and prodigies than in any other law, and the distinction of our race." Then those who speak against it:[46] "Nothing that has passed away was pleasing to God; they raged against his prophets; their race was always detestable to everyone; they are ordered by their own law to adore those gods who are worshipped by Christians and Mohammedans."[47] When this has burst out, again the Christian argues against the Mohammedan; this battle is tougher, and draws on great powers on each side, and is one on which the safety of kingdoms and provinces hangs. The Christian relies mainly on four foundations: first, the testimony of the prophets, with their so diligent tale of all that happened in connection with Christ, so that no one would take them as predictions, but would think them recounted after the event. They declare nothing about Mohammed. Next, on the authority of Christ's miracles—for instance, the &803 resurrection of the dead, of Lazarus[48] and the girl,[49] and the widow's son[50]—which were so great and extraordinary as to bear no comparison with the prodigies of the Mohammedans. But the miracles of the Mohammedans, the fall of stones from black birds,[51] or the concealment in the cave, as he teaches in his Koran,[52] or that he was sent or translated from Mecca to Jerusalem in a single night,[53] or that he was taken up to heaven, or that he split the Moon; all these either lack a witness, or are not miracles; stones falling from birds, even if it were prodigious and is accepted as having occurred, still do not make a miracle. For the Moon to look divided is neither miracle nor

[46] "Tum illi aduersus eam": it is unclear whether "they" are the Christians, and whether "it" is "the Jewish race," or even "the Jewish Law."

[47] "illos qui à Christianis ac Mahumetanis coluntur, à lege sua iussos adorari." The syntax and meaning are unclear. I have translated as if "adorari" read "adorare" and have passed over the fact that both Christians and Mohammedans worship the same single God; the use of "di" or "dei" in the plural when the reference is to God is not uncommon in the present work.

[48] John 11: 1-45.

[49] Matthew 9: 24–26; Mark 5: 39; Luke 8: 52.

[50] Luke 7: 12–15.

[51] In the Koran (105.2–4) the sending of birds to cast down stones of baked clay against enemies is described

[52] In the Koran (18. 9–22) it is recounted that the young men (the "Sleepers of Ephesus" [cf. *Oxford Dictionary of Byzantium* 3: 1883]) fled for refuge to the Cave and passed into a long sleep, "and they stayed in their Cave three hundred (solar) years, adding nine (for lunar years)."

[53] On the legend of the Night Journey (Isra and Mi'raj) see F.S. Colby, *Narrating Muhammad's Night Journey* (Albany: SUNY Press, 2008).

prodigy. To be transferred from Mecca to Jerusalem, or to have ascended into heaven, would be a miracle, but lacks a witness.

The third reason[54] depends on Christ's precepts, which contain nothing not consonant with moral or natural philosophy. For there is no one, even if very good, that can match his life, but anyone can imitate it. What is possible? Indeed, the further you depart from his example, the more you clothe yourself in a wicked way of life. But Mohammed endorses slaughter and wars, and a tower in Paradise, a Paradise in which people marry, beautiful boys wait at table, people eat flesh and apples, they drink nectar, they recline on silk couches, and they possess jewels and silk coverlets in the shade of plants. Who of healthy sensibility could tolerate this? Are they not absurdities, to represent God ascending to heaven from earth, and swearing an oath by the demons his servants?[55] What are we to make of the story (even if it is one, when it is more a fable) about the camel, repeated less than five times?[56] Finally, a conjecture is added for Christians, that with a few unskilled and &804 poor men against so many Emperors and wealthy sacrificers to idols, our law was promulgated, and took over the whole world, weakened as it was by internal sects.

But the Mohammedans themselves have[57] strong points. First, that Christians themselves do not practise the same simplicity in God Himself as they do,[58] and Christians[59] revere images, and appear as worshippers of gods, not of one God. There follows the argument from the outcome, since they have already won so many victories and occupied so many provinces, that the Christian law could barely be called a definite part of Mohammedan law, unless through our Emperor's goodwill another sphere had already been saturated throughout with the practice of Christian religion.[60] "One moment," they say, "probably God sup-

[54] i.e. "foundation."

[55] Here 1550 and 1554 run: "Absurda nonne est illa vox in Alchorano edita? Angeli et Deus pro Maumethe orant. Et quod fingat, Deum ascendere ad coelum e terris, et quod ipse etiam per Daemones seruos suos iuret."

[56] This brief mention may possibly relate to an account in the Koran of the presentation of a she-camel, and the recipients were warned to preserve it, but instead killed it. However, this account can be identified not "less than five times" but six times (7.73 with 77; 91.64; 17.59; 26.155; 54.27; 91.13).

[57] 1550 and 1554 include "quinque" ("five") here.

[58] Latin text present here in the earlier 1550 edition but removed from the 1560 and subsequent editions is translated in the Appendix at the end of the present Book. The removal was made to avert official suspicion of Cardano's religious orthodoxy; the passage was one that the earlier commentators regarded as atheistic or heretical: "locum impium et scandalosissimum, locum offensionis plenissimum" (Eckman, *Jerome Cardan*, 35).

[59] "Christicolae." The statement here about images etc. first appears in 1560.

[60] "ut vix Mahumetanae legis Christiana certa pars dici posset, ni beneficio Caesaris nostri . . ."—the sense may be that Islam was so well ensconced in Europe that

ports those taking the better view, and he does not willingly let down the many he could save with minimal help, as if he were against them." But their life and practices with positions reversed, when we appear as imitators of Mohammed and they of Christ, lend considerable authority to their law—they pray, they fast, they use simple worship, indeed the simplest, they refrain from slaughter, dice, adultery, and unprincipled deeds[61] against God, and unspeakable blasphemies, four faults by which the whole Christian population is almost crushed. What if you look at the good reputation of their women, and their mosque[62] worship? Finally, on miracles: they say we have them merely as records, and they have them in the present. Some fast for many days, others are burnt by fire and cut with iron, displaying no evidence of pain. There are many emitting voices from their chest, who used once to be called &805 ventriloquists.[63] This particularly

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Christendom almost seemed a part of it—then the New World came in to redress the balance. But "vix" cannot properly bear this meaning.

[61] "improba."

[62] "templorum."

[63] "engastrimuthi." This word is also used by Jean Fernel, *On the Hidden Causes of Things*, Bk 2, chap. 16. The modern use of "ventriloquist" to describe someone who creates an illusion that a puppet is uttering speech does not correspond closely to ancient usage. This word is a conversion of the Greek word ἐγγαστρίμυθος into Latin, a so-called "calque" of it. The Greek word's components are "within the stomach" and "speech," and in use it apparently refers to some style of utterance suitable for speaking on behalf of a spirit, or to someone using such a style. It is used in classical Greek literature, for instance in the Hippocratic work *Epidemics* (5. 63, duplicated at 7. 28), where a mortally ill woman makes a noise from her chest such as an ἐγγαστρίμυθος makes. Again, in the *Wasps* of Aristophanes (1019) a soothsayer is mentioned, and the ancient commentator on the play at that point uses the word to describe him. And Lucian's *Lexiphanes* (20) refers humorously to a character who imagines he has swallowed an ἐγγαστρίμυθος. This Greek word made its way into the Bible, though not into the original Greek text of the New Testament; it arrived in the Septuagint (third and second centuries B. C.), a translation of the Hebrew Old Testament into Greek. Dr Christoph Lüthy kindly pointed out that the original Hebrew does not contain any exact equivalent of the Greek word. In the Septuagint it is used of the "Witch of Endor" in 1 Samuel (described in the Septuagint tradition as 1 Kings) 28: 7–25, who had a "familiar spirit" enabling her to summon up from the dead the deceased prophet Samuel; Samuel then addressed Saul the ruler of Israel. It is not stated there that Samuel spoke through the mouth (or the stomach) of the woman, but that an apparition of him addressed Saul. There is in addition a girl in the New Testament (Acts 16: 16) who had a "spirit of divination" and persistently expressed her insight into the status of St Paul, to his irritation. The Latin version of the whole Bible (the Vulgate, produced in the late years of the fourth century A. D. and made the authentic text for sermons and disputations by the Council of Trent in 1546) does not use the word "ventriloquus." But various ecclesiastical authors later used it to refer to biblical soothsayers, among whom Fernel may have had in mind here either of these two candidates, the "Witch of Endor" seeming the more likely. Scaliger gibes at Cardano's brief mention of

happens to them while they are participating in some orgies and are rotating in a circle. These three feats are perfectly authentic, and constitute marvels to the natural reason, which we mentioned earlier; in contrast, there is the notorious faked feat, that children are born to women without sexual intercourse.[64]

But[65] the philosophers for whom this account was arranged have little concern with these things; let us pass on to the miracles of the provinces. Change of location makes so much difference that under each pole there is perpetual night for six months, and the same number of days following on it. In the nearest places there is night of four months, in those further away of two, or of a single month. Likewise in Nugardia,[66] once a very wealthy town, now under the king Moscho, still notable for a very extensive temple,[67] where honey emerges in the woods without cultivation, in summer a single daylight lasts many days, and this accords with the theory of the sphere, but what cannot be consistent with it is what Haitomus reports in the Hanse region (it lies between the Moschicum[68] and Antitaurum[69] mountains, not far from the town of Zoriga): that it is in permanent darkness, and therefore inaccessible.

And there is another distinguishing feature in regions, a feature drawn from heat and cold: any regions actually near the pole shiver with cold, while those under the belt which the Sun oppresses boil with heat; midway are the regions nearest to temperate ones. There cannot be populous cities under the poles, since the ground is sterile, and the transport of crops is difficult; hence people have to exist wandering about, or in small villas. Those who inhabit the temperate region have moderate cities; &806 they transport crops more conveniently into them, and live better and more safely in them than in villas—they are more secure with a crowd and within walls, and technical skills can correspondingly

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the word "engastrimythos" here, and displays much greater detail in his comment here (*Exercitatio* 258 [3], 795).

[64] Waters (*Jerome Cardan*, 222) indicates that this passage was expunged from the edition of 1560, and attributes this to the offence it caused to some, who interpreted it as referring to tenets of Islam and of the circumstances of the birth of Christ. But this is not true: this particular portion is present in 1560.

[65] This paragraph is a fundamental revision of the longer account in 1550 and 1554.

[66] Novgorod, some 250 km south of St Petersburg in Russia—a very old Russian city, founded about 860 A.D. Cardan remarks here that it is now under the Tsar of Moscow.

[67] The Cathedral of St Sophia in Novgorod was built in the 11th century. See M.S. Flier, "St. Sophia (Cathedral, Novgorod)," *ODMA* 4: 1451-52.

[68] Bohun (*Geographical Dictionary* [London: for Charles Brome, 1693]) names Ararat as one of the mountains there, along with "Paryadra, Masius, Niphates, and Abus," and so it evidently lies where Turkey, Armenia, and Iran adjoin.

[69] The Taurus range lies on the south side of Asia Minor, and these are ridges accompanying it.

help them better. Rome was different—because it had secured power over the globe, it happened to acquire not vast walls, but a vast population. In contrast, in hot regions, very large cities are needed, firstly because a part of the soil is either infertile through lack of water, or very fertile, if well-watered. Because of this lack of uniformity, when a suitable place for nourishing a large population is found, it is reasonable[70] to found a very extensive city, and to assemble a very numerous population into it.

There is another more potent consideration,[71] because when merchandise [553]comes from far, and through deserts and dangerous places, the merchants have to travel as a number together, and in the fashion of a column, for their safety. Hence when they have established their base in some city, it would be too much of a nuisance not just to the merchants but to the cities for this company to wander about. Thus it is better (and much easier) for all the neighbours to group themselves in that place; and when this goes on for many years, even from a little village a very populous city develops. Of this kind are Quisnai, Singui,[72] Cambala,[73] and Cairo. Gehoar the Illyrian slave built this city in Egypt for the security of Elcaim the Mohammedan priest, and it was called by the name of Pontifex Elcaira, and then Cairo, by a corruption of the name. If anyone mentions Byzantium, otherwise known as Constantinople, even though it has little claim to be compared with these cities that have a circumference of sixty or more miles, the reason is its &807 power.[74] In antiquity, no city was more notable than Lycosura in Arcadia; before it, says Pausanias, the sun had not seen a city.[75] It was built in the Lycean mountain by Lycaon son of Pelasgus.[76] Cities depend on their position and their men. A position should be healthy, impossible to capture, and easy of access. A position cannot be impossible to capture unless on a mountain, in a marsh, or on water. In mountains access is difficult, in marshes it cannot be healthy—so the Eternal City is to be placed on water. But not on any water—on water with plenty of shallows and fords. Shallows and fords are not enough either; in fresh water the air will actually get unhealthy. And if it is far from the mainland, it will either be overwhelmed by the sea, or the fords will

70 Reading "par," not the "pars" of 1560.

71 "causa."

72 Quinsai (not Quisnai) and Singui are both mentioned in Marco Polo's account of his travels (chap. 52 of Book I, in Ramusio, *Delle navigationi et viaggi*, 2: 45b) as lying between Tibet and Peking. There is mention there of Singui-matu too, "which is noble, large and handsome, and rich in merchandise and manufactures" and is also on the road to Cathay.

73 An old name for Ethiopia. The next sentence first appears in 1554.

74 The remainder of this paragraph together with the next one first appear in 1554.

75 Pausanias, *Description of Greece*, 8. 38. 1.

76 Pausanias, *Description of Greece*, 8. 2. 1.

dry up—if they dry up, it must perish of hunger,[77] because there is no room for navigation, and there can be no fields in the sea. Venice is such a site, and Singui, where there are six miles of stone bridges, and Quisnai,[78] where there are twelve miles, and in Amsterdam, town of the Batavians, or of Holland. All these are undoubtedly both very large and very wealthy.

So far as men are concerned, they have two parts: body and mind. We use our bodies for the instructions and commands of the mind. The mind cannot be pure, nor command the willing obedience of all, unless the purest component of it is separated and is in charge. This part of the mind is called the law.[79] It is only in a state that the law rules, human beings do not rule; and human bodies trained in military toughness, and a situation both healthy and safe and easy of access, can stay in permanent freedom, that is, be &808 long-lived. Such is the condition of the Venetians, so that title of sole or extremely free "city"[80] deserves application to the town of the Venetians. This is discussed elsewhere.

The third type of distinguishing feature is derived from language; one person differs from another more in this than in anything else, since the rest of the animals display the same emotions by the same sounds.[81] Man alone is no more understood by another man than a swallow is understood by a lion. I can hardly set out in a number how many differences there are between languages. However, there are six simple kinds: from the mouth, and these resemble whistlings; from the tongue within the teeth, from the tongue protruding; then these are double, for instance in the lips and palate; from the throat, and from the chest. Almost all these distinctions can be seen in Italy: the Florentines produce them with the gullet,[82] the Venetians with the palate, the Neapolitans with the teeth, the Genoans with the lips. In summary, the tongue produces speech in four[83] simple ways: sharp, bent back, higher, lower, and free. The Roman tongue is free, the English one is bent upwards. And fifty-six composite modes exist, to which are added six simple ones; from differences of voice production,[84] sixty-two kinds of speech. But these individual ones are altered according to the basis of their names, so that "homo" in Latin is equivalent to ἄνθρωπος in Greek, to "hombre"[85] in Spanish, even if there were no change in the production. And there is a certain difference in productions: either the same word is treated to several kinds of production, or some words with these and some with those—does

77 Reading "fame intereat" for the "fama intereat" of 1560.
78 On Singui and Quisnai see n. 72 above.
79 "lex."
80 "urbs."
81 "vocibus."
82 "gula." The details here first appear in 1554.
83 But Cardano specifies five.
84 "prolatio"; the translation is speculative.
85 "umbri."

not everyone know the endless kinds of languages? Among them are &809 those that do not easily link their names, such as Roman and Spanish. Some languages with remarkable success use composite names, such as Greek and German.

The final distinction is drawn from life style; for instance, there are people who eat human beings, and a kind of these still lives on in the New World on the island of Hispania. These people have to be wild, and have the same attitude[86] as wolves have to beasts of burden. The start was from dislike; then people were lured on by the taste, and by sloth, since all wickedness grows among human beings through its own additions, and finally punishment passed over into the practice.[87]

In addition to these distinguishing features, there are the natural ones of sex, age, and temperament, so much so that one human being differs from another more than a she-goat from a wolf. Human beings differ first of all in size, and those that are enormous are called giants, and those who are small, pygmies or midgets.[88] While many records testify that there have been giants, what particularly supports this is that in the time of Claudius Caesar, an Arab called Gabbara was nine feet and the same number of twelfths of feet[89] in height,[90] and if that is reduced to our measure, it occupies seven wooden brachia and a quarter with a sixtieth. In our own age it could look less marvellous, since in the New World an island of giants has been found. However, I do not know whether the one that our Italian Emperor showed, to considerable astonishment, had his origin from that island. But one point will do: Gabbara's size was extraordinary, since a big man does not fill up a length of three brachia. &810 I am influenced by the authority of people writing in the past about military matters, who decided that the middling height of recruits is five feet. So the old foot is a quarter less than the measure of our brachium; thus Gabbara was five brachia and three quarters, or nine twelfths—a measure double that of the general height of human beings his age. So it was to the point to say that a human being of such a size had not been seen either after the time of Claudius, or for a thousand years before Augustus.[91] Before the time of the Trojan War, Telamonian Ajax was of huge size. Pausanias in fact reports that his tomb was uncovered by a flood that gave access,[92] and on the knee was visible a kneecap[93] as big as the discus of a youthful

[86] "ratio."

[87] "inde sapore allecti, atque ignavia, cum nefanda omnia suis incrementis augeantur apud homines, in usum vindicta transiit." Syntax elastic and translation speculative; the "practice" is evidently that of cannibalism..

[88] "pumiliones."

[89] I.e. nine feet and three quarters.

[90] Plin. *Nat. Hist.* 2. 16. 74.

[91] The rest of this paragraph appears first in 1554.

[92] Reading "aditum" and not the "aditu" of 1554 and 1560.

[93] "rotula"; literally, "wheel."

pentathlete.[94] Since this is larger than the circumference of a [554]human head of normal size, it is clear that Ajax was bigger than Gabbara. The bones of Hyllus, which were uncovered at the same epoch as that of the Emperor Hadrian, appeared so large that they were thought to be those not of a human being but of a beast. Hyllus lived at the time of Hercules.[95]

So far as midgets are concerned, during the past year a man of full age and of one cubit[96] in height was being taken round in a parrot's cage. But the height of giants is just as useless for the experience[97] of the mind as the height of the body of midgets. There are other people of uncommon nature, not size, such as Colanus,[98] a diver of Catania (a town in Sicily), a citizen who &811 flourished (it is agreed) a little before our epoch, or indeed in our lifetime. He used to stay hidden underwater like a fish for three and four hours at a time. And this is not very remarkable, since in the West Indies at present pearl divers stay under water a whole hour, busy searching for oysters.[99] And they are of an extraordinary form, like Protophanes the Magnesian, who came out victorious on the same day in the wrestling and the pancratium[100] at the Olympic Games. When his body came to light again under the Emperor Hadrian, a single bone all the way from the neck to the groin[101] was found instead of the ribs.[102]

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[94] "He (a Mysian) said that the sea flooded the side of the grave facing the beach and made it easy to enter the tomb, and he bade me form an estimate of the size of the corpse in the following way. The bones on his knees, called by doctors the knee-pan, were in the case of Ajax as big as the quoit of a boy in the pentathlon" (Pausanias, *Description of Greece*, 1. 35. 5).

[95] This is hardly surprising, since Hyllus was the eldest son of Heracles (Sophocles, *Women of Trachis*, 55 etc.).

[96] See n. to 26 (1560) in Book I.

[97] "experimenta."

[98] Scaliger (*Exercitatio* 262 [802]) maintains that this man's name was really Nicolaus, abbreviated to "Cola," and that he should not be referred to as "Colanus."

[99] The rest of this paragraph with the five subsequent ones first appears in 1554. Nowadays professional Korean diving women without diving equipment can remain under water for up to about 82 seconds (S. K. Hong et al., "Diving pattern, lung volumes and alveolar gas of the Korean diving woman (ama)," *Journal of Applied Physiology* 18 [1963]: 457–65).

[100] This combined boxing and wrestling.

[101] "ilia."

[102] This was in 88 B.C. at the 173rd Olympics. "For the Magnesians . . . one of the citizens won at Olympia in one day victories in the pancration and in wrestling. Into the grave of this man robbers entered, thinking to gain some advantage, and after the robbers people came in to see the corpse, which had ribs not separated but joined together from the shoulders to the smallest ribs, those called by doctors bastard" (Pausanias, *Description of Greece*, 1. 35. 6).

And there were others more remarkable as it turned out, for instance the good fortune of Aristomenes of Messenia;[103] firstly, he was captured in a fight by the Spartans, and along with the rest of the captives was hurled down into Ceadas, a very deep underground pit, and after the rest had died in two days, he had lain among them as if dead. But he came back to life, and catching sight of a fox that was consuming the corpses, he seized its tail, and putting his cloak in the way, he was dragged to the place through which the fox had made its entry. There was there a very narrow passage, and he got out. And after begetting a son, he was captured again, and through the dream of a girl whom his son later married, he got away. Finally as an old man he died of disease, his son surviving him, and there was a persistent view that he was immortal, so that the people of Greece would assert many centuries later that he was alive and had been seen.[104]

No less of a miracle is that of Leonardo of Pistoia,[105] who had gradually brought himself to such a state that he only took food once a week. And under Pope Clement, seventh of that name,[106] there was a young Scotsman with red hair and (as was seen) of bilious &812 make-up;[107] he deliberately permitted himself to be shut away for eleven days without food, having at other times been accustomed to do so up to the twentieth day. And after persisting up to thirty days in this starvation, he received the reward for a miracle.[108] We have covered the causes of this previously.

What are we to make of Hamar the African,[109] who was ill with inflamed eyes[110] in uninhabited country, and smelt the sand and said, "We are already close to inhabited country"? And so he was detecting the smell of human occu-

[103] A traditional hero of Messenian resistance to Sparta, usually assigned to the Second War of 650 B.C. See Pausanias, *Description of Greece*, 4. 14.7-24, and *OCD*.

[104] Pausanias (4. 32. 4) reports that Aristomenes (see n. 100 above) was posthumously present at the battle of Leuctra in 371 B.C. "though no longer among men."

[105] About 35 km NW of Florence.

[106] Pope 1523–1534.

[107] "habitus."

[108] A detailed report of a carefully observed experimental fast (water only) which lasted 30 days is available in F.G. Benedict, *Study of Prolonged Inanition* (Washington, DC: Carnegie Institute, 1915), together with information on other fasts, some of even longer duration, and further information on earlier investigations appears in the Introduction to idem, *The Influence of Inanition on Metabolism* (Washington, DC: Carnegie Institute, 1907). The subject was a professional fasting man and performed similar feats on other occasions. A celebrated case of protest fasting to death in Northern Ireland in 1981 by Bobby Sands ended fatally on the 66th day.

[109] The Hamar are now a tribe in southern Ethiopia. The word also means a donkey in Arabic. It is possible that the story here is not about a human being but about a donkey that acquired the ability to speak.

[110] "lippitudo."

pation from Egypt when 480 miles away, and from the three towns Berdea[111] of Libya 1000 miles and 40 paces; a smell is carried on hotness and preserved by dryness, so that in those regions he could make out a foul odour, which the filth both of animals and of human beings breathes forth, since a dog would not be less smelly than the "colanus" fish.[112] There are other things like monsters, such as men with their lips and nose quite thick in the Cassena region of Africa among the Ethiopians.[113] There will be a laugh from someone unaware of the nature of things, who has not seen Hippocrates giving his account of the Big Heads and their causes, in his book on *Airs and Waters.*[114] And we ourselves have seen Iohannes Petrus Bosisius, son of a woodworker in our town, who used to live in the eastern part of the town beside a community of slaves—a youth of twenty or more, who never needed to cut his nails or happened to do so. We have carefully thought over the question whether perhaps we were being tricked, and we saw the tip of his fingers so well protected by flesh that nails would not be required nor convenient. But the nails themselves were short, and virtually cut back.

&813 We have also seen the three-year-old son of Bernardino Komeri the wood merchant; when he had recovered from a fever and convulsion; such distension under his thighs and palpitation was left over that his body was forever bouncing back[115] without his feet moving, as happens with some acrobats.[116]

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[111] Location not traced.

[112] "cùm non minus esset odore canis, quàm colanus piscis." Fish not identified; the modern Colanus is a microorganism present in the sea, not a fish.

[113] Not identified, though Hakluyt mentions a district of this name near Benin in West Africa.

[114] On Hippocrates see n. to Book V at 357 (1560). The account is in chapter 14 of the Hippocratic *Airs, Waters, Places* (trans. Chadwick-Mann, 103–4). The heads of newborn children were tightly bound to elongate them, and the treatise states that the elongation then became inherited and binding was no longer required in later generations. Glacken (*Traces on the Rhodian Shore*, 85) explains how the Hippocratic author is here using cultural differences to account for differences among peoples, by an (alleged) instance of the inheritance of acquired characteristics.

[115] "resiliret." This paragraph first appears in 1560.

[116] "circulatoribus."

Thus I recognised that the disorder they call the "dance"[117] is a disease and real, since the dance of a real female infant is imitated.[118]

Others excelled in their form, like Cratinus of Aegina the Achive,[119] the most handsome of men, after whom came Alcibiades of Athens.[120] Others excelled in their speed of foot, such as Ladas the Corinthian.[121] In cleverness the Cambaiensian Indians[122] are outstanding; it is from them that our numerical symbols reached us.[123] These are of enormous value in the theories of calculation. In fact cleverness in mathematicians and judgment in natural scientists is assessed by memory in a sequence of words. After the Indians came the Greeks, and after them the Spaniards, Sicilians, and Italians.

Instances of extraordinary strength are not lacking. A dancer carrying twins on his shoulders, as many more in his arms, and one child on his neck used to dance before us. Another acrobat used to lift with his hair a stone which four men could not carry, with another man taken up previously on his shoulders—this used to relieve the load. The same man—incredible to relate—used to hold a ship's mast in his teeth to start with, then he shifted it onto his shoulder, and from there to the other one, without making use of his hands, while the

[117] "saltatio." The description suggests "Sydenham's chorea," also called "St. Vitus dance," which is a childhood movement disorder characterised by rapid, irregular, aimless, involuntary movements of the muscles of the limbs, face, and trunk. The disorder, which is considered a manifestation of rheumatic fever (streptococcal infection), typically has an onset between the ages of 5 and 15. . . . The symptoms may appear gradually or suddenly, and may include muscle weakness, hypotonia (decreased muscle tone), and clumsiness . . . The disorder may strike up to 6 months after the fever or infection has cleared. See http://www.medic8.com/neurological-disorders/sydenham.htm accessed 24 Feb. 2008.

[118] "quoniam verae infantis assimilatur"—sense unclear.

[119] Cratinus of Athens (not Aegina) is mentioned in the *Deipnosophists* of Athenaeus of Naucratis (Bk. 13) as a "handsome lad" with a lover called Aristodemus. It is not clear that the reference here is to him.

[120] Alcibiades flourished c. 450–404 B.C. and was a brilliant Athenian politician and military leader, as well as being good-looking.

[121] Pausanias (2. 19. 7, 3. 21. 1, 8. 12. 5, 10. 23. 14) mentions Ladas as the swiftest runner of his day, and he won the footrace in the 125th Olympiad (280 B.C.).

[122] Cambaya is in India and corresponds approximately to Gujarat, where there is still a town of this name; it is the most westerly province of to-day's India.

[123] India was using them in the third century B.C. and they reached the Arab world about the seventh or eighth century A.D. Europe began to use them shortly before the end of the first millennium. They differed from Roman numerals by including the symbol for zero, which enabled any number to be represented by the ten symbols arranged in the now familiar (and crucial) order.

mast stayed upright all the time.[124] From antiquity it is accepted that Martius,[125] a Roman citizen, son of a smith, from the Spanish legions, was elected in place of the Scipios to the leadership, because he was so strong. He regularly &814 detained approaching wagons while leaning against a tree or stone—he could push or pull any of them where he wanted. He used to smite the enemy with a finger shut in his fist, so that only one joint protruded, and did so just as a club would have done. There is also a report about Sicinius Dentatus.[126] And it is agreed that Hercules too possessed strength of this kind as well as notable wisdom. The utmost strength of a human being of not more than moderate height is called into play if he carries a weight of a thousand pounds, which would be most conveniently done if he puts on a corselet[127] and leaden greaves. Though all this looks remarkable, there are four contributions: the nature of the climate, transmission,[128] feeding, and skill. Some regions, as I said, produce large human beings, others smaller ones. [555]It is possible to create midgets in just the same way, and dogs from Mljet;[129] they are born from a small father and mother, they are bound in tight bandages, they are not fed amply, but sparingly. How excellent if this discovery was as useful as it is easy! It is on the same principle that large progeny are produced from large parents, are trained and nourished amply, and not bound in bandages. But the principle is deceptive in relation to large size, not small size, strength and nature; divers are born spontaneously from divers, thereafter technique and patience assist nature; and though it is possible in all these cases to go ahead with never-ending addition, so far as human nature allows, there is a way back from there.

The Senega river (the province is at the limit of Africa on the western side) shows the extent of a region's influence, when those who live to the North on this side of the river are of an ashen colour and small body; but those who live &815

[124] The next six sentences appear first in 1560.

[125] Lucius Marcius (not Martius) (Livy, 25. 37–39; Loeb 6: 477–95), a junior member of the Roman army, took over the leadership after both the distinguished Scipios had been killed, and led a highly successful night attack upon the Carthaginians (212 B.C.). But Livy, while reporting a lengthy "speech" of Marcius to his army, does not mention the more sensational aspects of his feats described by Cardano; nor does Frontinus (*Stratagems*, 2. 10. 2; Loeb 189). So Cardano's source remains unclear.

[126] *Siccius* Dentatus was a largely legendary Roman tribune and warrior who died in about 405 B.C. and is described by Pliny (*Nat. Hist.* 7. 101–106; Loeb 2: 573; and see *OCD*) as an example of courage. He was, according to Pliny, celebrated for his valour in battle during a career in the Roman army lasting around 40 years. He could show the scars of 45 wounds on his chest, all received in battle. And so on. He has sometimes been called "The Roman Achilles."

[127] "lorica."

[128] "propagatio" –possibly transmission from father to son.

[129] An Adriatic island (*OLD*). Its "meliteus" dogs are also mentioned in Book X at 701 foot (1560).

beyond it are black, of tall build, and sturdy; in fact in this part the whole region is green, but the other part is barren.

Now to talk about upbringing:[130] one should observe how bastards[131] are usually immoral, and rarely come to good; they are originally born of worthless and immoral women, such as servant girls. Then others are from shameless, lying, gluttonous intractable whores, and since they follow their mother, they turn out like that themselves. Later their upbringing is neglectful. Usually too the father is possessed by a criminal and excessive love when he does the begetting. So the mother's nature has most influence, then education, finally the father's emotional state.[132] For bastards to be of honourable modesty, do not choose a servant girl or a whore, but a virgin, poor but honest, whom you will bring up with sound morals and moderation. If you have acknowledged sons from her and educate them liberally, they will be like legitimate ones. So select a nurse who is not blind in one eye[133] nor a drunkard nor sick nor immoral; one who is blind in one eye will make the infant so, not with her milk, but with habituation to her gaze.[134] A drunk one lays him open to a convulsion and weakens him, and renders him drunk and intemperate. A sick one makes him sick, a mad one makes him mad. The nurse has great influence on his morals and the shaping of his body, so much so that a nurse with dark eyes will darken the infant's eyes, even if they are white by nature. And those who associate with the infant do a great deal for his moral upbringing and the position of his eyes. So do not link a squinting servant or maid to him; choose a nurse with the sort of eyes you wish the boy to have.

&816 When the infant has been fed, see that he has these four things, which involve absolutely no expense, and consequently are available even to any pauper: a pretty name, charming manners, a nimble body, and ambidexterity, as Plato also perceived.[135] There are also other things, of more use and needing moderate expenditure, but not so available to the poor. They too are four in number:

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130 "institutio."

131 "spurii"—more precisely, sons of an unknown father.

132 "affectus."

133 "luscus."

134 "intuitus consuetudine."

135 Plato, *Laws*, 7.795a–c: "This is shown by the Scythian custom not only of using the left hand to draw the bow and the right to fit the arrow to it, but also of using both hands alike for both actions. And there are countless other instances of a similar kind, in connection with driving horses and other occupations, which teach us that those who treat the left hand as weaker than the right are confuted by nature. . . . it matters a great deal, and most of all when weapon is to be used against weapon at close quarters . . . in regard to the use of weapons of war and everything else, it ought to be considered the correct thing that the man who possesses two sets of limbs, fit both for offensive and defensive action, should, so far as possible, suffer neither of these to go unpracticed or untaught."

distinguished skill,[136] living in a city, knowing how to write, and knowing how to calculate. Above all, you need to take care that he doesn't become a thief; this is provided for by the following expedient: send him to various places before you assign him to the task of purchasing; observe him sinning, and the blows inflicted on him for this reason[137]—when he turns this over in his mind, that you know what he thought you did not, he will gather that nothing escapes you, and will take care in that way not to deceive you. Also, buy the necessaries, so that he does not need to have money—I say, the necessaries, all that you want to lavish on him. In this way you will bring him through to youth by employing skill; then, a human being of complete age, and sensibility and body, you should leave him to his own way of life.

But[138] if the intention is to convict a treasurer of fraud when he cheats you: receive an account in writing, pretend you have immediately lost it, request another, compare the two; and when they have not corresponded, you will appreciate that there is underlying fraud. But take care that you do not leave such a long time interval that he can reasonably plead that he has forgotten. When some people were proving a man's dishonest gift—a man who had already been dead for a day—and came upon the dead man's notebooks of expenses, which stated that he had been in another city, they had &817 the upper hand in the case. Other people introduce a man who sells by agreement,[139] then they look for the price in the accounts. These look small and well-worn points, but not too small to be much preferable to other more distinguished subtleties for saving family resources; despising or ignoring them has led to catastrophe even for the wealthiest men. And they are not so well-worn that there are not far more people that ignore them than those who convince themselves they know them.[140] There are in fact many more kinds of these, but on *Skills* we have written a considerable special book.[141]

This is the form of the perfect human body: the face is one tenth of the whole distance from the start of the hair to the end of the big toe. Divide this[142] into three equal portions: the interval from the top of the nose to the start of the hair, and from its bottom to the chin, so that the nose becomes one third of the whole

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136 "ars nobilis."

137 This seems the most credible interpretation of the Latin "atque verbera indicta causa," of which the syntax is obscure.

138 This paragraph appears first in 1554.

139 "ex condicto."

140 "nec tam pertrita, vt non longè plures haec ignorent, quàm qui se scire persuadeant." Tortuous unclear sense.

141 Presumably his *Technae calidae* (alias *De le burle calde*) is meant, which Maclean (*De libris propriis*, M90 [90]) calls "a fictional moralistic work in the genre of the 'burla' offering general advice about living," written in Italian in 1550 and subsequently abandoned.

142 The face.

face, and one thirtieth of the height of the whole body. The separation of the mouth, or its length,[143] is equal to the width[144] of the eyes, which extends from the outer angle[145] of the eye to the lacrimal one. But this interval is equal to the gap between the eyes, so that there is a threefold division, which is from outer angle of one eye to outer angle of the other, that is, both eyes and the interval between them.

This total is double the length of the nose, so that the width of an eye or the separation of the mouth is twice the ninth part of the length of the face; hence too the length of the nose is one and a half times the width of an eye and the separation of the mouth, and as it is thrice the interval from the bottom of the nose to the mouth, this interval will be half the separation of the mouth or the width of an eye. &818 The circumference of the mouth is double the length of the nose, and three times its separation. So the whole length of the face is one and a half times the circumference of the mouth, or of the interval set between the outer angles of the eyes — this interval is equal to the circumference of the mouth. The circumference of the nose at its bottom is equal to its length, but its length is equal to the length of an ear, and the circumference of the ear itself to that of the mouth. The nasal foramen is a fourth part of the width of an eye.

So they are set out like this:[146]

Face	18 parts
From outer angle to outer angle of eyes	12 parts
Length of nose	6 parts
[556]Circumference at bottom of nose	6 parts
Length of ear	6 parts
From hair roots to nose	6 parts
Bottom of nose from chin	6 parts
Width of mouth	4 parts
Circumference of mouth	12 parts
From top of head to lowest neck	24 parts
From top of chest to topmost roots of hair	30 parts
From top of chest or fork to top of head	42 parts
Circumference of ear	12 parts
Width of eye	4 parts

143 "longitudo."

144 "longitudo."

145 "Angulus *hircqui*" (or "hirci"); this term for the outer angle of the eye is vouched for by Castelli, although not used by Vesalius. Scaliger (*Exercitatio* 267 [811–12]) announces with a display of scholarship that it appears in Servius, but not in Celsus, Festus, Pliny, or Varro. He doubts whether it should be used.

146 The item "From top of chest or fork to top of head" appears as 36 and "From chin to top of head" as 24 in the 1550 and 1554 editions. There are also other amendments above the mention of Vitruvius in the discussion.

Separation of eyes	4 parts
From bottom of nose to mouth	2 parts
From mouth to chin	4 parts
Foramen of nose	1 part
&819 Circumference of top of forehead	18 parts
Palm of the hand from the joint where it is joined to the top of the middle finger	18 parts
From chin to top of head	30 parts
Foot	20 parts
Forearm	30 parts
Chest	30 parts
Whole body	180 parts

In addition, the temporal muscles correspond proportionately to the length of the face, and the ears to the nose, as we have noted. Also, the circumference of the heel where the foot bends is equal to the circumference of the calf—this is where the measurement is made for greaves. Again, from the knot of the hand to the top of the middle finger is a tenth of the total distance from the bottom of the nose to the top of the head, or from the top of the head to the bottom parts of the neck is double the interval from outer angle of eye to outer angle of other eye. From the root of the hair to the top of the head is as far as from the chin to the top of the nose. From the fork of the upper chest to the roots of the hair, and the boundary of the forehead, is as much as a forearm, or the width of the chest, that is, one sixth of the whole height of the body. The length of the foot is a ninth part of the whole body. Again, from the upper fork to the top of the head is forty-two parts. The detail[147] in Vitruvius should be altered to this effect, since the basis cannot stand, that the difference of an eighth and a tenth part added to a sixth part fills up a fourth part of the whole.[148] When the hands are outstretched, the height of the whole body is filled up exactly, and if you draw the feet and hands apart, &820 the navel will be in the middle, so that a square arises from the earlier figure, a circle from the later one, both the most perfect of figures in their own kind, the one of lines at right angles, the rest of

[147] "litera."

[148] What Vitruvius (*De Architectura*, 3. 1.2: Loeb 1: 159) wrote is: "For Nature has so planned the human body that the face from the chin to the top of the forehead and the roots of the hair is a tenth part . . . the head from the chin to the crown, an eighth part; from the *top* of the breast with the bottom of the neck to the roots of the hair, a sixth part; from the *middle* of the breast to the crown, a fourth part . . ." [my italics] In expressing this, Cardano has ignored half the length of the "breast," which evidently accounts for 7/120 of the Vitruvian total and balances Vitruvius's equation. Leonardo da Vinci's famous drawing of a human figure thus proportioned can be viewed as, for instance, plate 215 in Popham's *Drawings of Leonardo da Vinci.*

oblique ones.[149] Nature uses such precise care in measurement, but just as much in temperament and mixture; and so the time has now already come for discourse about these, starting from generation itself.

[149] Siraisi (*The Clock and The Mirror*, 271 n. 31) draws attention to the Renaissance enthusiasm for theories of human proportion, and provides references to recent accounts of its history.

Appendix

The following translates the Latin text found in the 1550 edition at the point indicated by n. 56 above:

"First, that Christians themselves do not practise the same simplicity in God Himself as they do, giving Him a son, and the Son himself a God. What if, he says, there were more than one God, and they were at odds with each other, and dominion did not rest with one, so that it could not be exercised by several without contention? He asserts that they wish to provide an equal or a son to God supreme over all, though He is very great, and in need of nothing, and eternal.[150] So in consequence of what Christians allot to Him, he asserts that heaven is in disorder, and earth has departed. He introduces a God complaining for this reason, and Christ excusing Himself, because He has not allotted this role to himself, but others have inflicted it on him.

There is a second basic point, one from Mohammed himself, that Christians revere images, and appear as worshippers of gods, not of one God."

[150] Christianity is here accused of what in Islam is called *širk* (*shirk*), attributing a partner to Allah, deifying that partner and thereby straying from monotheism. Denounced in the Koran 4: 48: "to set up / Partners with God / Is to devise a sin / Most heinous indeed."

[556] &820 Book XII
On Man's Nature and Temperament

When the paternal seed dominates the maternal one, the sons are mentally like the father; if the opposite, like the mother.[1] And if the paternal seed is in control of the menstrual blood, the sons are made like that father; if it is overcome, this makes the sons like their fathers in mind but like their mothers in body; the menstrual blood is generally more potent that the paternal seed, because it is plentiful, just as the paternal seed is more potent than the maternal seed, which is less and thinner. On the same principle, sons that mature more like their father are created when the mother is of tender age. In fact, males arise from heat and females from cold;[2] for what is more potently perfect overwhelms what is imperfect, through its plentiful supply[3] or the heat of its location.[4] Hence comes the way to procreate sons, which is threefold. First, the man should take exercise, and make use of quite solid food, and have intercourse less frequently—that way, the seed emerges hotter. Secondly, the mother should lie &821 on her right side, and after intercourse at once take rest on that side; Hippocrates[5] actually said that males are generated on right sides and females on left ones. Also of help for this purpose is the herb called male mercury, which has two (so to speak) testicles for seeds; the female has the bunches, on the authority of Dioscorides, from

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[1] Aristotle insists on this in *De generatione animalium* (4. 3; 768a22 ff.; Loeb 407 ff.].

[2] This was Aristotle's view: "Now the opinion that the cause of male and female is heat and cold . . . has a modicum of reason in it . . . All the same, to state the matter in this way is attempting to lay hold of the cause from too great a distance" (*De generatione animalium* 4. 1; 765a35–b7; Loeb 385). Galen (*De Usu Partium*, trans. Tallmadge May, 2: 636–37) explains the determination of sex by 1) whether the right (for female) or left (for male) uterus and testis are responsible for the fetus, and 2) heat (the male being hotter) can override 1).

[3] "multitudine." Instead of this clause, 1550 and 1554 state that males, being hotter, are likely to resemble their hot fathers, but females, generated from cold, their mothers.

[4] "quoniam quod perfectum est, potentius multitudine, aut loci caliditate superat quod est imperfectum."—syntax not clear.

[5] Hippocrates, *Epidemics II*, 15; Loeb 7: 85: "the male is engendered on the right."

whom Pliny got this.[6] I was gazing at these in our garden along with Thomas Iseus the physician[7] while I was writing this. By observing this second point,[8] many people on my advice have obtained their wish; the third point has not happened to be tried out yet.[9] As people say, it is a good plan after a recent purgation with iris root to place male mercury underneath, and offer it to drink with food, and when she has conceived, to give the leaves of the male flower to eat.[10] Along with the very small animals, it is characteristic of the human being to be able to have sexual intercourse and also beget all the year round. Since the mouth of the neck of the womb is always open, pregnant women can have intercourse, and if the mouth of the womb opens, superfetation can happen to them. Again, from a single childbearing perpetual lactation can occur. I knew a woman who after one and the same childbirth suckled three[11] brothers over an interval of six years. But the milk deteriorates with length of time after childbirth; uterine pregnancy and childbirth purge the blood. Again, after the renewed purging of the vessels in which the milk is created, when there is a new creation of milk it makes the milk purer. Some sediment is left in the vessels from every humour that is made by nature or art, and so long as its generation continues, it cannot be washed out.

[557]Again, twins are generated at the same time, and are born on the same day, on the testimony of Hippocrates.[12] And so the ratio of one part to another part in the Sun's motion exists in uterine gestation, since the &822 number of days[13] is the same, and the measurement of a day cannot be defined otherwise[14]

[6] Pliny discusses "mercurialis" in *Nat. Hist.* 25. 38–41 (Loeb 7: 165), mentioning its use to control the sex of the baby at the time of conception, but does not mention Dioscorides.

[7] Not identified.

[8] I.e. mother on her right side. The frequent emergence of the hoped-for outcome is unsurprising, since the chance is evens, and Cardano was an expert inaugurator of statistical theory! See Ø. Ore, *Cardano, the Gambling Scholar* (Princeton: Princeton University Press, 1953).

[9] The next 11 sentences appear first in 1560, to [A] on 822 (1560) and subsequent sentences first in 1554, to [B] on 823 (1560).

[10] The Aristotelian view was rather different; he advised that young parents are liable to produce female children, and that conception with the wind in the north would lead to male children (*De generatione animalium* 4. 2; 766b28–767a13; Loeb 398–99).

[11] The brothers were not necessarily her own children. V. Fildes, *Wet-nursing: A History from Antiquity to the Present* (Oxford: Blackwell, 1998), 176, refers to a case of a wet nurse taking 12 infants in sequence, and discusses the whole history of this service.

[12] In a Hippocratic treatise, *On Superfetation* (item 14; ed. Littré, 8: 484) is the statement: Ἡ τὰ δίδυμα κυέουσα τίκτει τῇ αὐτῇ ὡς καὶ συνέλαβεν (A woman bearing twins gives them birth on the same day, just as she conceived them too on the same day).

[13] Of each twin's gestation.

[14] Translating "alio," though "alsio" appears in 1560.

than by the Sun's movement in the same part.[15] Or the reason is that human nature, aroused by the first birth, cannot hold out more than a day. [A] I sense that I am now setting out on a huge ocean, in starting to talk about the hidden distinctions of human nature, of male and female, age and youth, of nations,[16] and of parts. Some of these actually differ so much that they are not regarded as of a single kind. Most of the Numidians have never washed their hands nor faces, and avoid drinking water; they have no sword,[17] but are satisfied by camels' milk and meat juice, a feast[18] so shabby that you would think them no better than beasts. How could you compare these uncivilised peasants with the luxurious and talented peoples of Cambaia?[19] The elderly take pleasure in things that suited themselves when young, like playing at dice—and they they do not tolerate with equanimity being beaten by enthusiastic youth. Hence the elderly prefer exercising their minds, the young exercising their bodies, pursuits in the range[20] that are totally different, indeed contrary. Old men are avaricious, gloomy, and nervous; young men are spendthrift, eager, and bold. So the pursuits of the different ages appear not so much contrary pursuits, as those of animals of a different species. Indeed, human nature (as has been remarked elsewhere) is seen to embrace the whole vast collection[21] of everything, and in its arrangement many major features lie hid; the menstrual blood from which it is assembled has great power. Indeed, a woman who is menstruating discolours a steel mirror with rust by her breath, and spoils any crops she passes. But again, the bathwater of her firstborn son, where the residue of her &823 blood is present, cleanses leprosy, as I have seen demonstrated. The cause is to be looked for in Sympathy,[22] in my

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15 Evidently there is an astrological concern here.

16 J.R. Hale (*The Civilization of Europe in the Renaissance* [London: Fontana, 1993], 51–66) discusses the stereotyping of European nations during the Renaissance.

17 The word is "gladium" in 1554 and 1560, although some word such as "granum" (a cereal) might be expected. The sense may be that they are primitive ill-armed people.

18 "convictus."

19 A state of northwestern India in the Gujarat division of Mumbai, with a substantial coastline on the Arabian Sea; the word is used for instance by Ralph Fitch in 1583 (See J.H. Ryley, *Ralph Fitch, England's Pioneer to India and Burma* [London: Unwin, 1899], and J.C. Locke, *The First Englishmen in India* [London: Routledge, 1930]).

20 The range of pursuits: "in caeteris."

21 "moles."

22 Sympathy ("consensus"; συμπάθεια), as an explanation for "action at a distance," was discussed by Galen (*De locis affectis*, 3.11; K. 8: 193–96) in connection with the genesis of an epileptic seizure It was also a regular feature of pathological thought in Cardano's time; for instance, in the *De abditis rerum causis* (trans. Forrester and Henry, 639, 643, 691) of Jean Fernel, a rather senior contemporary of Cardano, and in the works of Guillaume Baillou (1538–1616; cited in I. M. Lonie, "The Paris Hippocratics," in *The Medical Renaissance of the Sixteenth Century*, ed. A. Wear et al. [Cambridge: Cambridge University Press, 1987], 155–74, here 173), who reviewed the earlier work of Rhazes, Galen, and

view. This more corrupt blood, having made its entry through the arteries and veins of the leper, attracts corruption. The blood which has run out from childbirth is in potentiality like ours, and more corrupt, and in powers still is hotter than that of the birth and of a boy—hence it is powerfully stimulant, and purges, and extinguishes, just as the Sun's rays overwhelm the flame of a fire and make it vanish.

[B] But to return to my topic: I know that in the second book of my *Contradicentia Medica*[23] I have shown that all sons retain something of their father or grandfather with precision—I mean a wart, or scar, or likeness, or way of life, or lines on the hands. And so if these seeds are well mingled and linked to tiniest parts, sturdy babies emerge. This is why bastards are sturdier, since the violence of the love mixes the seeds[24] a great deal. Likewise, in the case of those who beget few offspring, and the seeds do not actually come together, the offspring are in better condition and stronger, because what was not coming together acquires a strong reason for mixing when mixing occurs. On the same basis, mules are much more long-lived than the horses and donkeys by which they have been produced. And this is not because they abstain from coitus, because some of them do not, yet live long, and horses that abstain from coitus are short-lived. The remaining conclusion is that this occurs through powerful mixing, because where there is powerful mixing, there is thinning of substance, and where there is thin substance, it is solid there as well. When things that need mixing differ, they require much movement to get thinned, and so they turn out thin and solid. The outcome is that two &824 men of the same temperament reach different spans of life, though following the same rule of life;[25] one will die in youth, the other at a great age. For someone will lead a very long life if he consists of compact and subtle substance, and a short one if of subtle and rarefied substance, a medium one if of thick and rarefied substance—for as I said, he cannot consist of compact and thick substance.

There are people who estimate the duration of life from the form of the teeth. However, Augustus, who lived to 76, had rarefied, small and rough[26] teeth—and glittering and darting eyes, like those of Alexander the Great, as Adamantius the

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Erasistratus, and explained the advent of right-sided convulsions after a left-sided injury to the head by sympathy; he reckoned that effects attributed to "absolute sympathy" (i.e. without contact) were not explicable in terms of shifts of humours or spirits.

[23] Initial publication in 1545; for full details see Maclean, *De libris propriis*, M13 (51–52). The second book is entitled *Circa artem medicam*.

[24] Male and female.

[25] "regimen."

[26] "scaber." This is the Emperor Augustus of Rome. The account is in Suetonius, *Divus Augustus*, chap. 77. Scaliger, however, not unreasonably condemns Cardano's reliance on a single example (*Exercitatio* 271 [817–8])!

Sophist[27] relates. Slender use of love-making also makes for long life and vigour, for during it a good deal is poured forth from that important arterial blood and the purest spirit,[28] because generating requires these, the generating for which love-making itself is established. It turns bodies to water, and upsets the brain and nerves and makes them tremulous, it speeds old age, and particularly weakens grey hair and the eyes. But since the arterial blood has been mentioned, it is right not to overlook that there are double veins in us: one set thin and immobile on the very surface of the body, in which the blood is warm and red, the other thick and pulsating, in which tawny and very hot blood is contained that proceeds from the heart, while the starting point of the original blood is the liver. These thicker veins pulsate together with the heart and with the same timing,[29] and by this movement the natural heat is preserved, and anything sooty that gathers is expelled—while they are dilated, they are cooled, and while they are contracted, the soot is expelled. The strong pulse, the need to breathe,the fire of the body, and the drip of sweat after a run show that heat &825 is stimulated by the movement itself.[30] But to get back to the benefits of breathing: all animals breathe, either openly or without being noticed. Birds, snakes, and quadrupeds moderate their heat in air; fish moderate their heat by their gills in the water. The evidence is that when transferred into air they suffocate, as do quadrupeds

[27] He wrote a Greek treatise on physiognomy in the fourth century A.D. and Cornarius had turned it into Latin in 1544.

[28] On orthodox belief in Cardano's time about the composition of semen and how it was achieved and spirit included in it, see Jean Fernel, *Physiologia*, Book 7 (trans. Forrester and Henry, 523–601)

[29] On the then disputed relationship between cardiac contraction and *arterial* contraction, see J. J. Bylebyl, "Disputation and Description in the Renaissance Pulse Controversy," in *Medical Renaissance*, ed. Wear et al., 223–45. Cardano seems to be referring to the much less obvious *venous* pulsation, not mentioned in (for instance) Fernel's contemporary *Physiologia*, and not properly resolved till the beginning of the twentieth century. And Cardano's reference here to "tawny and hot blood" in *veins* that proceed from the *heart* is not orthodox Galenism; Galen regarded pulsatile vessels as arteries by definition, and held that the "pulsatile power" originated in the heart and proceeded thence along the arteries (see Charles Singer, *Galen on Anatomical Procedures* [London: Oxford University Press, 1956], esp. 177). Veins, in contrast, drew their blood and powers from the liver. An odd light on Cardano's remarks here is that in fact in a warm limb the surface veins are dilated and are carrying warm blood back to the heart, while in a cold one they are contracted and most of the blood is returning in deep, invisible veins.

This note bypasses the issue of naming the pulmonary vessels.

[30] 1550 and 1554 here include some 5 sentences on whether life can be prolonged by a preparation made by converting gold into liquid form, citing Raymond Lull sceptically as claiming that the Emperor Frederick III reached the age of 100 by this expedient.

in water in their turn.[31] Crabs can make use of water and air for breathing, and use both moderately. Flies, mosquitoes, and silkworms obviously breathe. You can barely see the slow walkers breathing—the crab, the tortoise, the snail, the beetle, the chamaeleon, the salamander;[32] the reason in their case is that when movement is frequent, frequent and extensive respiration is needed; when movement is small, fast and extensive respiration is not needed. Hence large animals that breathe little and slowly have short lives, as oxen do; small respiration is evidence of small heat, which cannot control a large bulk for long.

But the major sign of long life is to grow much and slowly. Next to this comes growing little and slowly. But if growth is much and fast, it indicates a short [558]life—but if it is small and fast, it is evidence of a very short life, for moistness that is very easily stretched is also quickly consumed; what is slowly consumed is fatty and compact, and very little watery, and for that reason too is not readily stretched. That is why the elephant, then the human being, and then the camel (which sometimes reaches its hundredth year) are regarded as having the longest &826 life.

I have learnt from the archives of the record-keepers[33] that from the birth of my great-great-grandfather Aldo to this day, 269 years have already flowed by, so that no family in Italy is regarded as more long-lived. Almost the same has been the case on the maternal side, and from my great-grandfather Aloysius till to-day 170[34] years have elapsed. The reason for longevity in a human being is extreme heat and abundance of moist fattiness, and uninterrupted rarefaction.[35] But the reason for shortness of life is much dissipation.[36] Man is therefore very hot by nature, and very moist. Hence he is of bad morals; from heat has emerged something cruel, deceitful, unreliable, and bad-tempered. From moistness something feeble, languid, intolerant of work, and a lover of pleasures, combining gluttony with licentiousness. This is also why wise men, being of a very hot nature and very moist, are the worst of all unless they make progress in philosophy. In that, they are helped by the industry they have acquired from their studies, and by melancholy, which is generated by the dissipation of fattier humour from excessive studies and lack of sleep. So to say that wise men have suffered dreadful things and then done them is only to say that they have followed their nature, and that the study of philosophy has not made progress in them. And dissipa-

[31] 1550 and 1554 include here material on the respiration of fish and dolphins, removed in 1560.

[32] 1550 and 1554 include "ascalobotum," a gecko.

[33] "monumenta tabellariorum."

[34] This figure is updated here in 1560 from the figure given in 1550, but only by 3 years!

[35] "tenuitas solida."

[36] "resolutio"; also means "paralysis" and "loose bowels." Moistness is to undergo "resolutio" just below.

tion of moistness is a cause of shortness of life, as abundance of it is of longevity. On this theory too animals live less long than plants—they had to move, and so to possess heat that would consume; with the heat consuming the moistness, as I said, life would be shorter. Again, if rarefaction is linked to solidity, it is useful to &827 everything, pleasant and welcome—and even essential in small creatures. Being of thin substance, bees are therefore sagacious and live long, up to seven years. So Vergil writes: "The seventh summer is no longer extended."[37] The ant too lives long, as long as the bee. There are people who extend the tortoise's life to sixty and more years, on the basis that they grow much and slowly, an argument that applies (as I said) not only in human beings but also in all animals and plants. The tomb of Duke Alexander of Florence[38] shows that among all, the human being is of the thinnest substance, as is that of his fat; although the tomb was made of the whitest and densest marble, the corpse's fat made its way through; the tomb was fouled by a stain, and then so was the base, with droplets dripping onto it from the columns. Although the corpse of Alphonsus Avalus[39] was dried with numerous medicaments and then with salt and sand,[40] the fat penetrated the lead, trickled down from a space onto the stones below, and fouled them—and this though the bodies of the dead are not of such rarefaction as those of the living.

Thus there are two outstanding gifts to mortals that emanate from the rarefaction itself, as if from a parent: long life and distinction.[41] Man is therefore, of all the land animals, the most ready for sexual relations, because he is hottest and most moist; he is worsted by the birds, because they ejaculate quite a small amount of semen, &828 even in proportion to their body, and because they have internal testicles. Because they contemplate, wise men are less inclined to sexual relations, since their spirits are dispersed on account of their study, and are conveyed from the heart into the part opposite to the genitalia, that is, towards the brain; hence they beget sons that are weak and are very unlike them. And so it is a help to associate a great deal with pretty girls and to read an erotic tale—besides,

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[37] Vergil, *Georgics*, 4. 207; the poet is indeed here writing about the longevity of bees.

[38] Alessandro de' Medici (1510–1537) was made Duke of Florence in 1530 after the capture of the town by the Emperor Charles V. He was assassinated by a distant cousin, and hurriedly buried in the cemetery of San Lorenzo. For details of the murder see C. Hibbert, *The Rise and Fall of the House of Medici* (London: Allen Lane, 1974), 255–57. But the stained tomb is not mentioned there.

[39] Alfonso d'Avalos (1502–1546), from a Spanish family. Marchese del Vasto (district on the Adriatic coast of Italy, roughly on the latitude of Rome), military commander of Spanish and Italian forces, and rival of Ferrante Gonzaga. He died at Vigevano on 31 March 1546. Details in *Dizionario biografico degli italiani* and *Enciclopedia italiana*, but the tale about his body is not mentioned there.

[40] "sabulum."

[41] "nobilitas."

to have beautiful virgins painted on their bedrooms, and never completely to cease sexual activity for a time, especially since when it is occasional, there is nothing better to relieve anxiety. Baths are also helpful to those who are too relaxed on account of their loose structure.[42] But penile erection occurs from a thicker inflation, and sometimes while it is being pushed down[43] the penis erects because of eagerness or pity. I used to see the penis erected in some people who were being hanged, and this is a species of convulsion. Again, in some people the imagining of someone else's distress arouses desire, so much so that (as Ioannes Mirandula records) there was a man who would not erect unless he were being beaten,[44] and many who would not unless they were giving a beating. Others too are prevented from sex while they are blushing or frightened, and suppose themselves the target of poisoners.[45] There are meant to be many ways to treat this problem: flying ants embedded in what is called elder-tree oil and smeared on the penis, and many others already mentioned and to be mentioned later, which concern the imagination and the medicaments. But what a venesection does for a plethora,[46] and a bath for weariness, is what is done by sexual intercourse with the man lying on his back, for people who believe themselves bewitched—if the woman is &829 on top of the man, and his penis is drawn up towards his stomach by its own bonds and cannot topple because of the bonds, nor be retracted to the stomach because it is in the vagina, then it is compelled to release its semen, and when that is expelled, the man gradually grows accustomed to lie face down. Sex is established by habit, and so it is difficult to withhold it from a woman who is used to it. It is withheld from virgins, when habit plays no part for them, and so they say they are not providing help. This is also why those who are busy at sex cannot be interrupted.

Avulsion of the testicles quenches and removes sexual desire. Beyond that, it prevents baldness,[47] and prevents a beard growing, by bringing on almost

[42] "textura."

[43] "detruditur."

[44] Count Giovanni Pico della Mirandola (1463–1494) was an influential figure in the Florentine Renaissance. In Book III *Disputationum adversus astrologos* (in his *Opera omnia* [Venice, 1519], fol. Z ii r) Pico describes the case of a man who only "ad venerem accenditur" (a more delicate expression than Cardano's "non arrigebat") on receiving a vigorous beating, and who insisted on the beating being fast and drawing blood. On Pico generally, see M.V. Dougherty, ed., *Pico della Mirandola: New Essays* (Cambridge: Cambridge University Press, 2008), and S.A. Farmer, *Syncretism in the West: Pico's 900 Theses*, MRTS 167 (Tempe: ACMRS, 1998).

[45] On Cardano's own impotence, see n. at 370 (1560) in Book V. The remainder of this paragraph appears first in 1554.

[46] "plenitudini."

[47] Aristotle, *Historia Animalium* (3. 11; 518a28; Loeb 1: 205), "and neither of these [conditions of baldness] occurs in a man until he has entered upon sexual activity. No boy or woman or castrated man ever goes bald; if castration takes place before puberty,

opposite effects; and it protects a man from gout. But if baldness or falling of the hair occurs for another reason, oil of tartar[48] is the best medication, and restores the falling hair, and makes hairs not yet started begin to grow. And so nature does nothing without good reason, since it is the celebrated heat that summons forth the hair. But this oil is extremely thin, and significantly hot.

But he [the human] was going to be heavy, because of the heat and the humour, and therefore lacked wings; they would get in the way of the arms; he could not actually [559]fly. Four feet were needed, but then he would be looking downward with his head; so he could only stand on twin legs, upright, and without help, and needed very large and long feet.

And so no animal has larger feet than the human being. The same applies to the rest. But as Galen has written on this &830 exhaustively in his *De Usu Partium*, there is no reason for me to repeat what he has well stated.[49] This single point should be noted: the parts of a human being are so subtly perfected that if the upper teeth were bent a little inward, they would fall out very quickly; if outward, quickly, but not so quickly—for in the course of speaking and eating, when they do not meet each other precisely, they weaken each other, and consequently fall out.[50] This is what befell my friend Marc'Antonio Maioraggio,[51] certainly a most learned and eloquent man.[52] While the even array of the teeth is most convenient for speech, it is not ideal for cutting; dogs and wolves have uneven teeth, arranged like a saw. They also mesh together better,[53] and do not retain the remains of meals so much. And so some of the Indian peoples, who

the later growths of hair do not take place . . ." See also J. B. Hamilton, "Male Hormone Stimulation is Prerequisite and Incitant in Common Baldness," *American Journal of Anatomy* 71 (1942): 451–80.

[48] A concentrated solution of potassium carbonate (Crosland, *Historical Studies in the Language of Chemistry*, 104).

[49] Galen wrote at length about the foot, hand, and leg in his *De Usu Partium*, book 3. 138 (trans. Tallmadge May, 164). But he did not write that "no animal has larger feet than the human being," and it would have been odd if he had believed this. The nearest equivalent is: "From all these examples it is clear that feet must be broad and elongate to give steady support, and that this is the reason why such feet have been provided for man who, more than quadrupeds, needs stability in locomotion." (K. 3: 138; trans. Tallmadge May, 164)

[50] In *De Usu Partium* (11. 8; trans. May, 517) Galen's statement is much more modest: "Imagine that the molars lie towards the outside, the incisors and canines towards the inside: would not all their other qualities be of no avail?"

[51] Marco Antonio Maioraggio (Latin form Marcus Antonius Maioragius) died in Milan in 1555 at the age of 41. He had been professor of belles lettres, famed for the elegance of his Latin. See P. Bayle, *Dictionnaire historique et critique*, new ed. (Paris, 1820), 10: 142–48.

[52] The following five sentences first appear in 1554.

[53] "Melius etian haerent hi invicem."

are not so concerned with a developed form of speech, adjust their teeth with a file to take on the pattern of a saw. They mesh more at the root, since they do not meet at the top; those that actually meet at one side are easily disengaged at the other. But if oblique ones do not meet, just as when a tooth has been completely extracted, they make speech stammering.[54] Teeth do also emerge in old age, and later than anyone reckons, but such occurrences should be reckoned miracles, not in accord with the general rule. At Genoa I have seen Antonius Benzus, from a town at the port of Mauritius,[55] thirty-four years old, pale, with a scanty beard and a fatty constitution, from whose breasts so much milk flowed that he could almost have suckled an infant; it not only used to &831 run out, it squirted out.[56] He was a soldier, and all his life had put up with considerable inconvenience. In infants this is not remarkable.[57] Recently the wife of Martinus Borglinus, a friend of mine, who had already been barren for fifteen years, gave birth to a son, who during his first month discharged plentiful milk from his nipples, and they grew so hard that the midwives used repellents and evoked a vomiting of milk, not having looked after the earlier condition.[58]

But to return to the makeup of the human being: the bone of the head has to consist of a number of pieces, so as to be more secure; when one part is broken, the whole does not have to be impaired, so that veins and arteries can enter and the sooty excretions can leave more conveniently. Nature joined the parts with very slender sutures, so that they could be held more firmly together, to prevent the brain's heat from vanishing, so that a smaller entrance would be open for cold, and so that membranes would stick more firmly to them; and though the sutures were slender, the bones are quite thick. However, if the head bones were abnormally thick, they indicate that their owners are unteachable, too unafraid of beasts, and absent-minded. As Oviedo[59] reports, such bones exist in Hispaniola[60] in the Indies, and are so hard that the Spaniards have agreed together

[54] "blaesus."

[55] Not identified.

[56] "impulsu ferebatur." T. Laqueur (*Making Sex* [Cambridge, MA: Harvard University Press, 1990], 106) writes that Cardano, "court physician to the King of Denmark" (a post Cardano in fact declined when it was offered to him) stated that "at some places nearly all men had much milk in their breasts."

[57] I.e. for milk to emerge from the breasts of the newborn. The rest of this paragraph first appears in 1560.

[58] "affectus."

[59] Gonzalus Fernandus Oviedus. On Oviedo see n. to 128 (1560) in Book II. In his *Historia general y natural de las Indias* (Book V, end of Proem, in 1: 111) he reports that Indians in Hispaniola have heads and bones of the head so hard, large and thick that when fighting them, Christians take care not to hit them on the head, for fear of breaking their swords.

[60] On Hispaniola see n. to 127 (1560) in Book II.

that their heads are not to be struck even if unprotected, because the swords get broken.

Herodotus[61] says he noticed the same thing on the heads of Egyptians: when they had been shaven and exposed to Sun and showers, they get hardened, and this happens in our &832 regions too. Strong heat has this ability, especially when not lacking in matter. Hence such people do not easily go bald nor grey-haired; their skin is more compact, and their heat is better controlled by moistness. They also have harder bones and membranes, and harder cerebral substance, so that for the most part they are stupid, absent-minded, and hard to teach, because the membrane of the head that surrounds the brain has to be very thin in moderate people, in case it harms the brain by its heaviness, and correspondingly harder, so as not to allow its substance to split in concussions. It cannot be thick either without disaster for the brain, unless the brain itself is thicker than it should be. Another membrane is placed evenly over it; since it could not weigh down the brain, because it is suspended from the bone, and does not touch the actual brain, it was made not only hard but also thick.

A similar care extends even as far as the hair: since the head lacked flesh and needed covering, nature devised hair for a very light and safe cover, and arranged that it should grow a great deal, since on other parts hair can turn out long without assistance; in this part, nature attended also to beauty, so much so that it established a more powerful portion of beauty in hair, not just in women, but also in boys (whom the ancients used to treat as sweethearts). Thus golden shimmering hair is outstanding, and is accepted as very thin and very charming; but the further dark hair declines from an attractive colour, the thicker it is too.

But in the human being, nature has displayed many instances of thinness, but none approaches the &833 degree of subtlety seen in the face. Two marvels follow on from this: one, that in such a vast number of human beings and such a tiny extent of human face, everyone is so distinguishable from everyone else that not only can no two people be alike, but they have identifiable features. Second, that nature sometimes has embellished such a small part of the human body with so much beauty that we willingly wish to die for it, and are driven to madness by the torment of a form no longer seen. At times nature adds such ugliness that it arouses nausea and revulsion at the memory alone, though it is not befouled in the construction of both eyes, of the nose, mouth, teeth, forehead, and cheeks.[62] A further, third feature of this part, one itself a revelation[63] of the cunning of

[61] Most of this paragraph is revised and expanded in 1560. The reference here is to Herodotus, *Histories* 2. 36.

[62] "Quamvis in utraque structura oculorum, nasi, oris, dentium, frontis, genarumque haud sit oblita." The syntax and meaning are not entirely clear. I have translated "oblita" as derived from "oblino," although it could validly be derived from "obliviscor" and mean "forgotten."

[63] "argumentum."

nature, is that by small changes of the face, the distinctions and kinds[64] can be seen of the happy person and the sad one, the bold one and the fearful one, the angry one and the pitying one, the loving one and the hating one, the hopeful one, the desperate one, the healthy one, the sick one, the dying one, and the numberless other conditions of the mind and body.[65]

There is now another revelation internally of the marvellous subtlety and diligence of nature: the partition of the lung, by which the [560]trachea is separated from the venous artery;[66] air makes its way freely through during inspiration and expiration, but there is no way out for the very thin blood enclosed within the venous artery. It is thus remarkable on what basis Galen presumed to say that spirits are thinner than vapours,[67] since vapours make their way out freely, while the spirits stay inside.[68]

&834 So this will be the order of the parts of the human body: the thinnest part of all is spirit, then bile, next fat, then marrow,[69] next arterial blood, then milk, next venous blood, then black bile, next phlegm, melancholia,[70] brain, lung, flesh, spleen, liver, veins, arteries, nerves, membranes, ligaments, cartilages, and bones — the thickest. The narrowest of the passages are (as mentioned) those that lead from the trachea into the venous artery,[71] next come those that lead from

[64] "species."

[65] Physiognomy, the relation between outward appearances and personal character or temperament, was considered early by Hippocrates and by Aristotle; a treatise on physiognomy is attributed to Aristotle (Pseudo-Aristotle, *Physiognomica*; 805a–814b; Loeb 85–137) and he also touches briefly on the topic in his *Historia animalium* (1. 8–11; 491b9–493a5). Galen discussed their contributions in his own commentary on the Hippocratic treatise on the humours, especially chaps. 7 and 8 (K. 4: 795 onwards). Metoposcopy, a portion of physiognomy, is devoted primarily to the significance of the lines on the human forehead, and to some extent to such items as birthmarks elsewhere, as indicators of a person's character or destiny. Predictions of the future and deductions about the past can, it claims, be achieved. Cardano himself wrote a *Metoposcopia* in the 1540s and expanded it in 1550 (see Maclean, *De libris propriis*, M58 [75]) But it was not published until 1658. On this and in general see A. G. Clarke, "Metoposcopy," in *Astrology, Science and Society*, ed. P. Curry (Woodbridge: Boydell Press, 1987), 171–96; he reviews doubt about the authenticity of this published work and on the whole supports it (172). A later major contribution is J.C. Lavater's (1741–1801) *Essai sur la Physiognomie* (1781), translated into English by T. Holcroft (2nd ed., 4 vols., London, 1804). Physiognomy was under hot criticism by his time, and is defended here. See Martin Porter, *Windows of the Soul: Physiognomy in European Culture 1470–1780* (Oxford: Clarendon Press, 2005).

[66] The pulmonary vein.

[67] Statement not identified in the works of Galen.

[68] A passage in Galen to this effect has not been traced.

[69] "medulla."

[70] Since "melancholia" means "black bile," it has already been mentioned just before.

[71] These were the pulmonary capillaries. Galen deduced their existence, but they were first visualised in approximately 1661 by Malpighi, who could see with his

the right to the left ventricle of the heart, through the interventricular septum.[72] Then those where the branches of the portal vein are linked to those of the vena cava within the periphery of the liver. None of these is visible to the eye, but they are discovered by the reason alone.[73] Afterwards come those that lead from veins into arteries, then those of the bones, then those of the skin, which are obvious to the eye, and through which the hairs grow out—and we usually call them by their Greek name of "pores."[74] These are so essential that if they are constricted or blocked, a fever makes its way in. Exhalations pass through these all the time, and often sweat, occasionally blood, hence bloody sweat, when through mental distress a thin blood thinned out by fiery heat is squeezed out—although Aristotle, in the third book of *De Partibus Animalium*, ascribes this to cruelty.[75] And in seventh place come the ends of the veins and arteries, through which the actual blood makes its way into the solid substance of the organs.[76] There is a sequence common to these five transmutations, through which blood is transferred into dew, then into the hollows of the organs, next it is attached, linked, assimilated, so that the impure part is detached, and the thinner and &835 more compact remainder is reduced to the point where it reaches the substance of the organs. Scarcity of blood does not properly support the powers and the body; similarly, an excess is oppressive, both in itself and because it reveals that the body is not being nourished, because very plentiful blood must also contain refuse. When blood is nourishing the body, the veins are thinned out, and the body is enlarged. In old age at any rate, flesh can be restored, but in youth it too is solid. An animal and a plant are enlarged, because the pattern of enlargement is the same in both, since it is nature's work, while what is enlarged can extend.

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microscope the blood traversing them in the frog lung. His paper is reproduced in J. F. Fulton, *Selected Readings in the History of Physiology*, 2nd ed., (Springfield, IL: C.C. Thomas, 1966), 68–71.

[72] On the celebrated pores linking the right ventricle of the heart to the left by penetrating the interventricular septum, see C.D. O'Malley, *Andreas Vesalius of Brussels, 1514–64* (Berkeley: University of California Press, 1964), 281. O'Malley refers to the 1555 revised edition of the *De Fabrica* of Vesalius, which is more emphatic than the first edition in asserting that the pores do not exist.

[73] That is, their presence is deduced from physiological considerations.

[74] Cardano in effect includes as "passages" the blind ends of hair follicles.

[75] "In some cases, the sweat consists of a blood-like residue; this is due to a bad general condition, in which the body has become loose and flabby, and the blood watery, owing to insufficient concoction, which in its turn is due to the weakness and scantiness of the heat in the small blood-vessels" (Aristotle, *De partibus animal.*, 3. 5; 668b6–9; Loeb 253). Aristotle's καχεξία is reproduced by Cardano's "crudelitas," but does not mean "cruelty"; the "bad general condition" of the Loeb translation here is apposite.

[76] "membra."

As Alexander[77] has correctly explained, the way in which anything is enlarged is like this: supposing the softer shell[78] of an egg is nourished by its contents, the form will remain, but the matter will be changed. Thus since all the cavity which is in the body is full of juice, it is extended, while the form remains; hence enlargement follows the form, which remains—not the matter, which is always being added to it. Because it is being enlarged or nourished, it should remain, and it is in that that it differs from generation. In every addition that is made to the body, some portion is separated, and the rest is thinned out and made more compact. This occurs too in the generating of semen and of milk.

Furthermore, milk is compact, and thin, and since it is also sweet, it nourishes correctly, besides anything else it does. Hence too it contributes very greatly to longevity; after it come olive oil, and honey; and it is just as useful as they are, but rather unsafe in case of clotting. So it should only be taken &836 fresh, and from goats fed on slender herbs, and rather young goats too, and should be drunk direct from the milking pail, and be allowed to settle.[79]

But someone will be uncertain: why are more compact[80] things thinner?[81] The reason is not obscure: thin things stick together correctly, and do not let in cracks or pores; this makes them compact. So concoction, which separates off the refuse, is thinning, and brings about condensation, and at times makes the product heavier, and at times lighter. Where it separates little or not at all, it makes the product heavier, as in fruits, which when ripe become heavier.

To return to the topic we were dealing with originally: a cause of longevity arises from compactness of matter; next to it is the contribution from aids to life;[82] then from rule of life;[83] the fourth place belongs to good supply of fatty moistness; the last place is allotted to the air. Britain extends human life to the one hundred and twentieth year.[84] But they live much longer in India; Nicolaus, a Venetian count, reports that while near a Portuguese town on the shore of the

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[77] Alexander of Aphrodisias, evidently, although the reference has not been traced. On him see for instance 117 (1560) of Book II.

[78] "cortex."

[79] "quiescendum"; since this parallels "bibendum," it probably refers to the milk, not to the drinker taking a rest afterwards.

[80] "densiora."

[81] "tenuiora."

[82] "vitae auxilia."

[83] "regimen."

[84] The interest in Britain here and below may reflect Cardano's visit to Scotland to treat Archbishop Hamilton: on that visit he reached Britain in June 1552. Young (*On Centenarians* [1899]) reviews British and other views on longevity, and (145) notes that Cardano, the "Admirable Crichton" of his period, suggested in *De Subtilitate* that length of life was dependent on a lessened amount of exercise; trees live longer than plants because, from fixity of position, they can obtain little exercise; for exercise increases transpiration, and transpiration reduces life. A highly selective version of Cardano's discus-

Red Sea in 1539, a native man was brought to the leader of the Turkish army (called the Bassa in their own language) who on the testimony of all the neighbours had reached more than his three hundredth year. It will not be possible to find such a long life always, nor everywhere in India. So search should be made for an account of such people, and from the account search for the underlying reason. It is a hot place, and consequently has thin pure air because of the winds, as it is on the sea coast; because of the waters it is also barely dry at all. Because of idol worship the diet is free of wine and flesh (&837 particularly beef), and comprises superb fruit, because of the temperate weather, and sugar. Thus over a long sequence of time and of generations, the lengths of life have gradually increased—first to a hundred years, then to 120, 150 and 170 and 200—finally the one closest to the extreme end halts beyond 300, as do all mortal things. We actually said that in the course of long propagation, everything changes for the better or the worse; thus beautiful, large, small, tiny-eyed, like the inhabitants of a region of China; strong like the women of Tarnaffati (this too is a region of India) who follow their race's custom in throwing themselves onto the fire on their husband's death,[85] while they talk about their lover, and tolerate without change of expression a cloth moistened with oil and set alight to burn on their bare arm, not even interrupting the conversation they have started. This endurance has grown up not from custom nor from the region, but from stubbornness against suffering reinforced through numerous offspring, so that the weakest[86] sex gives rise to greater examples of fortitude than those we admire in one Mucius Scaevola the Roman;[87] being gained with great difficulty, it possesses great power. And it is like the person talking to the worn-out man sowing palms, [561] "For whom are you sowing? For your great-grandsons? This has brought to a stop concerns for greater things. And so, supposing you look for such length of life from food or a district, you have tried in vain. And do not look for it in your son, but if you persist, it will turn up in your great-grandsons." We have spoken of food and of aids to life in this book, as well as in many others. Solid substance is produced by food and exercise, as these include plenty of fatty moistness. But considerable doubt &838 remains about the air: does thin or thick air contribute

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sion here! The remainder of this paragraph and the first part of the next sentence first appear in 1554.

85 The Indian practice of suttee, the suicidal self-burning of widows, was recorded in classical times (Diodorus Siculus, 19. 33–34), and finally legally forbidden from 1829. See http://encyclopedia.jrank.org/SUS_TAV/SUTTEE_an_English_corruption_of.html, accessed on 24 Feb. 2008.

86 "infirmissimus"!

87 In Rome's early history, Gaius Mucius Scaevola failed to kill the Etruscan leader Porsenna, inadvertently killing Porsenna's secretary instead. Captured by the Etruscans and being threatened with being roasted, to show his indifference to pain he held his right hand in a fire to its destruction (Livy, *History of Rome*, 2. 13).

most to longevity?—some think thicker air, since it is the air close to the sea, the sea is moist, and moist is thick. What is thick also seems to cause less damage. But if we think correctly, anything living in a thinner element is more lively, just as fish are more lively than worms, land animals than fish, birds than land quadrupeds, because birds live in purer air than quadrupeds. Worms actually live a very small life; they live in the ground, and are cooled only by the moistness of the ground. As I have said sufficiently elsewhere, moles do not live in earth, but under earth. Therefore where the air is thinnest, life is longest; such air does not consume anything worth notice. Consequently anything that lives in the ether lives so long that it could be called eternal. There are also people who prolong life without detriment right to extreme old age, such as Laurentius Bonincontrius, whose handwritten book on astronomy remains with me;[88] Lippus Brandolinus in his little book on the state of human life[89] records an octogenarian with such an intact memory that anything that had happened to him as a child and anything he had read in youth was so well preserved in his memory that you could believe he had seen or read it that day. The greatest help not just towards longevity but towards avoiding the drawbacks of old age is a moderate diet, without over-indulgence in strong wine or sexual activity, also a cheerful mind, and prolonged sleep, with exercise; make no use of medication or bloodletting. The ideal &839 air is pure and breezy[90] and moist and stirred by winds from the East. Britain has moist cool air, and its saltiness makes it nearly free of decay. A dietary system based on milk is highly favourable to longevity; Hippocrates actually wrote that the weaker foods make life short.[91] So people who are more compact live longer, and the opposite of this compactness is not softness but slackness.[92] So soft people can be long-lived, but slack ones hardly, or only

[88] Lorenzo Bonincontri was born in Tuscany in 1410 and died in Rome in 1491. He was a prolific author of history, poetry and astronomy/astrology (*Dizionario Biografico degli Italiani*, 12: 209-11).

[89] Aurelio Lippo Brandolini (1454–1497) was born in Florence and later lived in Rome and Naples; his numerous works include a commentary on Vergil's *Georgics* and philosophical studies. The treatise here mentioned is evidently his *De humanae vitae conditione et toleranda corporis aegritudine* (Basle, 1498) (*Dizionario Biografico degli Italiani*, 14: 26-28).

[90] "perflatus."

[91] Hippocrates, *Ancient Medicine* 9: "If the matter were simple, as in these instances, and both sick and well were hurt by too strong foods, benefited and nourished by weaker foods, there would be no difficulty. For recourse to weaker food must have secured a greater degree of safety. But as it is, if a man takes insufficient food, the mistake is as great as that of excess, and harms the man just as much. For abstinence has upon the human constitution a most powerful effect, to enervate, to weaken and to kill. Depletion produces many other evils, different from those of repletion . . ." (Loeb 1: 27) I am indebted to Professor Elizabeth Craik for this reference.

[92] "laxitas."

with great inconvenience; a human being could not escape softness, but could escape slackness. For beyond the fact that a human being was going to be very moist, and so far as possible free of an earthy part, and therefore soft, and with elements that were blunted, the consequent advantage developed that his senses operated very easily and precisely. This is why boys have thriving senses and are endowed with softer flesh compared to men, and among their organs the brain is soft, since it is the basis of all the senses.

But to return to duration of life: Indians by nature live very long, so much so that in certain parts some of them live a hundred years, some a hundred and twenty, some a hundred and fifty years—the air there is better, and the foods, and the habits,[93] and so life too is longer and sounder.

I feel that nature has fashioned four products with the utmost attention: of these the first is the human being with a certain divineness,[94] not to mention the rest; I reckon the elephant in second place, because of its longevity and docility, along with its so compact skin—a human being has a soft one. Among the gems, the diamond, for its glitter and hardness &840 and because fire does not spoil it. The fourth place is kept for gold, since it is of a very thin and pure substance, it is attacked by no rust, does not yield to water or fire or time, and is as much heavier as diamond is lighter.

These are the benefits of subtlety. But starting by drawing our illustration from the egg, look at how much help it also offers in generation itself. First, then, with heat incubating it, the hen's seed gradually turns the well-known egg white into tubes,[95] and then some of the yolk, since the wings and legs are made from the yolk. This is evident because chicks from a double-yolked egg, without separating membrane, are born with one head, but four wings and the same number of feet, and are taken as a prodigy such as occurred at Milan in the past.[96] And so whatever is enclosed in the bubbles is shaken and dried, and passes across into the membranes, nerves, and harder parts. Then what is is created first is artery and vein, and a place for the heart exists where the semen actually is. Consequently since the semen is in the middle of an animal, what is first generated should exist in the middle. This is the heart and liver. But what is close by, round the membranes, is less dry, and so a single membrane wraps everything round inside, and the bones must be covered with membrane all round. And so there was the same scheme[97] of inevitability[98] in generation and of usefulness in the

[93] "consuetudo."

[94] "divinitas."

[95] "fistulae."

[96] Scaliger (*Exercitatio* 288 [859]) asserts that Hippocrates held that the chick was the product of the yolk, but Aristotle held that it was the product of the white, and the yolk was its food.

[97] "ratio."

[98] "necessitatis."

generated things, evidently so that there could be a midway transfer from the utmost hardness to very soft things. But when the heat is further increased, the spirit, so to speak, bores through the matter that is supplied from the egg or from the mother, &841 till it reaches the egg membrane—but in the case of a quadruped giving birth viviparously, till it reaches the womb. So heat and motion and the tube[99] and drying and shaping follow upon each other, till the animal is created. Animal heat is not always essential, but in some cases is preserved in eggs, as in the case of fish. In other cases the fetuses have to be brought up in the belly, as in vipers. In some cases the eggs are extruded but remain attached to the body till the fetuses are born, as in the case of crabs. In other cases something resembling maternal heat suffices, and this is the way in which chicks are produced from eggs without a hen. Fill up two cushions[100] with hen droppings finally ground up, then stitch soft and thick hen feathers to each, and put the eggs on one cushion with the thinner end sticking out, put the other pillow on top, and finally put the combination[101] in a warm place and let it be undisturbed for two days; afterwards turn them over until the twentieth day so that they get equally incubated all round. Then on the specified day (around the twenty first) pull the cheeping chicks gradually out of the egg. It is unsurprising that in Egypt they need no assistance at all, though Aristotle says they are incubated underground at Syracuse.[102] In our own time it has been found that a gentle fire and dung can be placed underneath to produce chicks, [562]but from numerous eggs few chicks emerge. People put fire underneath to prevent the dung cooling. It is really not remarkable that chicks should be hatched by the heat of dung, since fetuses are produced of themselves from the eggs of both crocodiles and ostriches; it is in fact the Sun's heat that does the generating, helped by the heat of dung and of the hen. Though fiery heat does not generate anything, it removes and disables an obstacle; &842 cold is one. So not all eggs generate, nor even the majority; a minority contain such an amount of heat. Thus they require a slight heat, not a great deal—but this slight heat must be kept up. If in fact what is alive in potentiality could come truly alive from the heat of a fire, chicks would be hatched with the help of fire not only in Egypt and at Syracuse, but even in Germany, seeing that before animal bodies are brought to completion, they are in potentiality in respect of soul, and prepared to take it up; having done so, they are in

99 "fistula."

100 "pulvinaria."

101 "reliquum."

102 "They are hatched by being incubated by the parent bird, though they can also be hatched spontaneously in the ground, as occurs in Egypt, where they are buried in dung-heaps; and there is a story of a drink-addict at Syracuse who used to put eggs in the ground under his sleeping-mat, and went on drinking continuously for a long enough time to hatch them"! (Aristotle, *Hist. animal.* 6. 2; 559b1–5; Loeb 2: 225–26). The following six sentences and the subsequent one after "Germany" first appear in 1554.

potentiality in respect of actions. On their own they are at rest, and as long as this continues, it is called sleep; when they are resting because of lack of an object,[103] they are not really resting,[104] but in possession of a respite. While forms are being completed and the thing is being generated, it assumes incomplete forms without number, but because these are not recognised (unless through their own accidents), the power of sense does not grasp their number. Thus incomplete forms are infinite in number, but complete ones can in each epoch be grasped by number; since matter is limited, and because it[105] has a complete soul, it demands a fixed quantity, there cannot be an infinite number of sorts[106] of things. But it is for the books *De arcanis aeternitatis*[107] to consider whether a soul could be more a soul than another one;[108] I planned in the present book to deal only with what can be subjected to true demonstration.[109] True demonstration, according to Aristotle, is demonstration in which the power of sense endorses what has been proved by demonstration.[110] Hence in the present work I have left out all the very lofty questions, and the &843 indefinite ones.[111]

But to return to the principles of generation and nutrition: that both of them are brought about by hotness and moistness is understood from the following line of thought:[112] that when woollen cloths are being stretched or aligned, first of all people moisten them, then they hold them to the fire, shape them and pull them about. So if those that are wet and hot too are skilfully stretched, it can be done much more than is natural. Concoction is carried on by heat that is drier than the heat used for generation or nutrition, because what is sweet is also very well

103 "obiectum."

104 "non quiescunt."

105 The form, presumably.

106 "species."

107 On this work of Cardano, see n. in Book I at 5 (1560).

108 "utrum verò anima magis anima sit alia, ad libros . . ."; the meaning is unclear.

109 "demonstratio."

110 Cardano is excusing his inability to deal with the mysteries of the soul here by claiming to be concerned only with those things capable of true demonstration. He thereby invokes the Aristotelian distinction, in the *Posterior Analytics*, between "knowing the fact" [τὸ ὅτι] and "knowing the reason why" [τὸ διότι], which became known among the scholastics as "demonstratio quia" and "demonstratio propter quid." True demonstration was achieved only with the latter, in which the information provided by the senses was endorsed, as Cardano says, by an explanation involving supposed causes of the phenomenon in question. For a discussion, see S. Nadler, "Doctrines of Explanation in Late Scholasticism and in the Mechanical Philosophy," in *Cambridge History of Seventeenth-Century Philosophy*, ed. D. Garber and M. Ayers, 2 vols. (Cambridge: Cambridge University Press, 1998), 1: 513–52.

111 The following two paragraphs first appear in 1554.

112 "argumentum."

concocted; such things as watermelons[113] are recognised by the bitterness of the stalk and the strong smell and the thickness of the skin; these are all the result of dryness rather than wetness. And this is why the nutrition of the human body is optimal, because the body is moist and very fatty.

The whole is self-consistent, and as Hippocrates[114] said, it breathes through and permeates the human body, so much so that you could hardly operate two limbs at the same time with different motion or at different timings. Thus the measurement of time is more steady when two limbs move than just one. And contact makes its way between bodies and minds, and dispositions[115] and defects do so from minds to other minds, and from bodies into bodies. All sympathy[116] takes place through contact. Contact is fourfold: either with the body, such as with the skin; or with the matter, as in ulcers; or with an element, as in the plague; or by ray and likeness[117] alone, as in the use of the eyes. This makes obvious which are the contagious diseases: those around the skin, such as lepra,[118]

[113] "pepones."

[114] "et vt dicebat Hippocrates, totum transpirat et permeat corpus humanum, adeò vt duo membra simul diuersis motibus aut temporibus uix agere queas." Hippocrates (*Places in Man*, I. 6) discusses the interaction of the parts of the human body (and soul); for instance, "One part pushes, the other pulls; one part gives, the other takes." But probably Cardano has drawn from Hippocrates via Galen in Latin, as some of the language in the following passage indicates: "Cum dixisset igitur Hippocrates, in totius corporis ex membris compagine omnia compati et consentire, partis autem cujusque particulas ad ejus actionem conspirare: aequum mihi visum est, sermonem hunc prius in his partibus, quarum manifesta nobis est operatio, explorare, ut a quibus ad alias transire post liceat . . . Partes corporis omnes sibi invicem compatiuntur, id est, in famulatum unius operationis omnes conspirant . . ." (Galen, *De usu partium corporis humani*, 1. 8; K: 3. 17–19). I am indebted to Professor Elizabeth Craik for enlightenment here.

[115] "affectus."

[116] "consensus"; on sympathy, see n. 22 above. The passage here is modified in 1560 from the version of 1554.

[117] "similitudo."

[118] Jean Fernel's *Pathologia* (Bk VII, cap. 4 end) defines lepra as the worst of the four types of "impetigo" (rough dry skin with huge itching. Unlike scabies, it is dry and free of humour and gore). The first is simple *pruritus* (itching); second is *lichen*, a true impetigo, rougher, spreading; can go on to psora, and psora to lepra. Third is *psora*, with thicker, drier, harder, puffier skin, with cracks. *Lepra* erodes deeply, scales (pale or darkish) fall off, it is unresponsive to treatment; the common folk usually seek divine help. With psora and lepra there is gradual wasting, according to Fernel. On lepra, see also K. F. Kiple, ed., *Cambridge World History of Human Disease* (Cambridge: Cambridge University Press, 1993), Section VIII. 80, 834–39.

psora,[119] scabies,[120] vitiligo;[121] ulcers amid the lungs, and chest, and throat, and &844 genitalia, such as the French lues;[122] pestilent diseases around the heart and brain, and inflammations of the eyes.

But I return to the point from which I digressed. A very long life for the human being was essential for consideration and knowledge of everything; these are restricted around the hundred and twentieth year, if not earlier. But it is a rare event to reach so far without considerable drawback; however, Moses is said to have reached that age without deterioration. Indeed, neither was his eye weakened, nor did his teeth fall out[123]—the two greatest troubles that vex the elderly. And this is much less remarkable, since many of the Jews reached this age after him, but not in such good condition. Short of being divine, Moses is to be regarded as having been a notable man, for having ruled a people so stubborn and rough for so many years, and he handed down to them a law of such use. But longevity came to the Jews because of their dietary scheme, in avoiding unclean items, and because of the temperate climate under which they used once to live.

But why do teeth fall out in the elderly, while in the other animals they become unsightly? In the beginning, extra teeth were required, in case the loss or erosion of one made the rest suffer. Then the front teeth ought to be more slender and quicker to erupt, because they were going to fall out first. They could not easily have persisted like that, and so nature did not wish falling teeth to be reborn—the back ones not at all; they were sufficient to match the longevity of the front ones, even like that. Without the front ones—that is, when they had fallen out—there was &845 no use for the back ones. Thus as the bones were drying up with age, the roots of the teeth had to thin out and could not stay in place, since they were not gripped all round by the bone. Hence a person can no more dispense with trouble from his teeth than he can with old age or death. In addition, the brain's unending labour leads to dryness of the bone, which leads to poor coction and to premature ageing of the adjoining parts; therefore the teeth have to become scaly, and finally fall out.[124] They come out once in childhood, to

[119] Mentioned in Pliny (*Nat. Hist.* 20. 4; Loeb 6: 5) and in other authors, but Adams on Paulus Aegineta 4. 2 (trans. Adams, 2: 15–23) reviews the ancients on this and lepra without reaching a firm identification.

[120] This is mentioned about 40 times by Pliny.

[121] On vitiligo see n. at 798 (1560) in Book XI.

[122] Syphilis; this appears to have emerged in Europe for the first time in 1493, spreading rapidly, and was generally believed to be an import from the New World, though the title here used implies a French origin. On its history see Jon Arrizabalaga, John Henderson, and Roger French, *The Great Pox* (New Haven: Yale University Press, 1997) and Cardano's own treatise on the French disease.

[123] Deuteronomy 34. 7: "Moyses centum et viginti annorum erat quando mortuus est; non caligavit oculus ejus, nec dentes illius moti sunt."

[124] The next three sentences appear first in 1560.

be re-created, since the root has not fallen out. Because of its softness it is joined to the mandibular bone, but in people who are already grown up, the root generally falls out at the same time as the tooth. But if they are only broken, and not from the bottom, they grow again. They are found to be longer-lasting and firmer in dogs and other animals, because these have short lives.

Dimness of the eyes comes on because eyes need much spirit, and thin spirit,[125] and old age lacks both of these. However, a human being can take care to use some skill and protect himself from this trouble better than from damage to teeth. Teeth deteriorate or improve too because of foods; there are people whose teeth are weakened because the gums are eroded and defective. On the other hand, I have seen a man in whom prolonged vomiting of acid humour had made his gums grow so much that they overlaid the whole of his teeth. As I think there is nothing so like this humour as vinegar with a sediment, this experience induces me to believe that if one washes one's mouth with vinegar and black sediment, one's [563]gums will take on a significant growth. Since it is in fact astringent, it also erodes the stony material that develops &846 [wrongly numbered 446] between the teeth, by which the gums are eradicated. And drinking beer spoils the teeth, as is obvious in those who take it.

We spoke about the range of drinks; I regret not having included breads. I say nothing about the few nations that use a bread made of dried fish ground with a millstone and then submerged in water, as their custom is. There are five cereals from which bread is usually made: near the North, from soft wheat;[126] in temperate and hot regions, from normal wheat.[127] But normal wheat is of two kinds: the Asian, which is darker, less heavy and sweeter than ours, and does not grow in ears but in a tuft[128] like millet, and not such a soft one, since a number of ears make one up. In the West Indies they make bread with maize seed, and wine from it too. It is the fruit or seed of a herb, with a stem and stalk and leaves exactly resembling our sorghum or "milica" (Pliny calls it "loba,"[129] a red and larger kind of Indian millet), and the actual stem is surrounded with leaves, which does not happen in the Italian sorghum, but I think this happens because of the change of district; this one is sweeter too, but fragile like sorghum, and not

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[125] The allusion here may be to the ancient belief that vision was mediated by a "visual spirit" which emerged from the eye. On this see Lindberg, *Theories of Vision*, esp. 38, and note that this belief can be "proved" by covering one eye and noticing that the pupil of the other eye dilates — the so-called "consensual reflex"; the dilatation is then attributed to the blocking of the emergence of "visual spirit" from the covered eye, so that more has to emerge from the uncovered eye.

[126] "siligo."

[127] "triticum."

[128] "coma."

[129] Subsequent scholarship indicates that Pliny's (*Nat. Hist.* 18. 55; Loeb 5: 225) word was not "loba," but "iuba," the hairy part or mane of anything.

fatty or tough.[130] It produces a yearly crop with the same fertility, and the more ample where the climate and earth are more in agreement. I would rightly make bold here to call the despised sorghum by its proper name, maize, or call maize sorghum.[131] Ethiopia has its own "taphus" [teff], a grain more excellent than corn, because it does not get corrupted. Rice is a general food everywhere, since it grows everywhere — there is water everywhere.

&847 [wrongly numbered 447] The fifth kind of bread is made from the "hyuca" root.[132] This herb resembles hemp, but has a root very like the carrot, but larger; the inside is shiny white, the outside is rough, and almost of a vinous colour. What is remarkable in a species of this is that it reproduces the human condition: bread is healthy for the human being, and what is made from this root with the juice squeezed out keeps for a year; the juice itself if drunk kills on the spot, and this cannot be healed by any helpful step. So as I have said, death is linked to health, and is forever at rest.[133] While they are making the bread, this is why they carefully expel all the juice, juice that it is agreed belongs to the kind of hemlock juice, but is stronger; those who are meeting a voluntary death kill themselves by drinking it, supposing that it brings a gentle demise. In the places where we use corn, soft wheat[134] is the sureties;[135] if it runs short, millet is the guarantor[136] for both.

So[137] that we can grasp what the role of bread is normally held to be, and being held, what and how many constituents it can have, I regard it as essential to know what its properties are. They are five: for it to nourish well, to offer solid feeding, to please the taste, and in addition not to be readily tainted, and be easy to find. So seeds or fruits or vegetables or roots or flesh cannot be bread; flesh gets tainted, and if salted is unpleasant; roots and vegetables do not nurture well; fruit is drying, and seeds are unpleasing to taste, and most of these deteriorate with time.

So it is clear that every sort of bread should be treated by fire, otherwise it is not very pleasing to taste and cannot be of the most outstanding value &848 as food. Two features appear linked as a rule: among the Germans bread is actually produced from soft wheat and pure corn, and is better than wholemeal;[138]

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130 "lentus."

131 The following two sentences first appear in 1554.

132 This word suggests "yucca," but what is meant is the manioc root, which has to be processed to eliminate the toxin.

133 "perpetuò cubat."

134 "siligo."

135 "vades": the people who stand surety for the appearance of some person in court.

136 "praes," a surety who guarantees the production of money for a legal purpose.

137 The material here up to the start of the description of the Mamey tree first appears in 1554.

138 "autopyrus/os," whole meal from wheat.

the dough is well crushed, and is softer, and salt is mixed in, and what is called a decoction of wild hops[139] instead of water. And if this bread has been made out of wheat, it is much esteemed too by the French and Italians. But among the West Indians, in addition to the above mentioned plants, the role of treats is taken by the fruits of the "Mamey" tree,[140] the size of a huge peach, with a skin rougher than a pear, harder and more compact, of a rusty colour, and quite a rounded shape. The actual flesh is of a finger's depth, the colour not unlike bark, the taste like a quince. In the middle is a stone like a bone, and surrounded above the bone by a thin membrane, of a very bitter taste, but of a substance just like a chestnut, and this is cloven, sometimes even into three, and in that it differs from the quince, which otherwise it closely resembles.

There is also the "Guanabanus" fruit, from a tree the shape of a pine tree—a fruit the size of a watermelon, skin the thickness of a finger, liquid inside instead of a kernel, of a pleasant and welcome taste, with seeds quite like pods in size, shape, and colour; the tree is spreading, with long wide leaves; the fruit is very healthy, can be easily cooked, and never decays.

Now there are individual and special characteristics in all races that nevertheless come together in the general plan, not just in what concerns nature, &849 but also in ways of life. All people use bread, yet the matter from which it is made is diverse; they all use some healthy pleasing drink, yet there is one or another according to the region. So while their relations and connections are dying, almost everyone shows distress, and they alter their way of life and the basis of their worship; the result is that some grow a beard who did not use to, others grow hair who used to be shaven; others shave hair who used to grow it as women do; others relinquish a beard who used to grow it; those who normally use dingy clothes have shiny white as their mourning colour; those who normally use brilliant ones have matt black. Thus we see that there is the same principle in everyone's grief, but different practices during grief. Tears and sighs alleviate grief; sighs extract from the heart the soot held there by sorrow, so as to cool the heart; but tears squeeze out the overheated part of the blood's water, so that spirit can make its way freely through. Thus since the sorrow from grief and the sleeplessness are regular invaders,[141] we will be freed from peril by sighs, tears, and fasting. I am by nature loving of my family, more than is normal. So when my mother's sister Tomaxina had lost her husband, two sons, and two daughters from the plague, and was reluctant to weep and lament in the usual way, from a sister's respect for my father, a serious and harsh man, she suddenly gave out a great noise and dropped dead, heart-broken inside. I know of others who have

[139] "lupus salictarius."

[140] The description of this fruit is much modified in the 1554 and again in the 1560 edition.

[141] In 1550 and 1554 this passage refers to the death at the turn of the year of his wife Lucia Bandarena, as well as to that of Tomaxina's husband and children.

rapidly died from pernicious fever, carried off because of concealed grief for a brother. And for things to turn out very well and to avoid death ensuing, the sure reward of restrained grief is grey hairs. [564] &850 So when the onslaught has moderated a little, arm yourself with philosophy and hold out against grief by its precepts. But to reflect on this straight after the grief is neither easy nor safe.But you will say: "If general human practices are shared, why are languages different, and the various kinds of speech?" This occurs through the nature of places, since Italians have great difficulty in producing their voice with their chest, but Hebrews do this very easily, and can hardly speak at all except with some sort of loud noise; hence translated speech deteriorates when it does not take on its own pronunciation. Common people, too, carelessly producing it, spoil and contaminate it; so the diversity of languages always takes its origin from the common people, the masses triumphing. And so with a jumble of races and diverse languages at market days, there are always other words turning up, and as they make their appearance just as people too do, inevitably their predecessors pass away. The value derived from the diversity of languages is that all the conditions of the mind can be expressed. The evidence for this is that you could not have expressed a sentiment of Homer in Latin or in our mother tongue, nor one of Vergil in Greek or our mother tongue, much less could the feeling in the poems of Franciscus Petrarch[142] in his mother tongue be put into Latin or Greek. Just as there is this value in diversity of languages, there is business in their resemblance.[143] However, in most races a double language was in use in the setting up of trade; there was also the one that distinguished the plebeians from the patricians, as in the case of the &851 Romans, on the evidence of Cicero.[144] Hence this debated problem: did Cicero, Livy, and Sallust write in their mother tongue? It is established that there was a second language, more polished than that of the plebeians, but not differing from the mother tongue as much as ours differs from Latin. And you will see this clearly if you compare the style[145] of Vitruvius, a plebeian, with that of Cicero, a man of consular rank. Similarly, nowadays the Greeks have a common and hackneyed language different from that in which so many distinguished books by ancient Greeks are expressed. And the Turks have

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[142] Francesco Petrarca (1304–1374), a poet and scholar and early humanist in Italy and France. See C. Kleinhenz, "Petrarch," in *Encyclopedia of the Renaissance*, 4: 451–58.

[143] The remainder of this paragraph first appears in 1554.

[144] "Don't I seem to you to talk in the language of common folk ["sermo plebeia"]?" (Cicero, *Ad Familiares*, 9. 21. 1; Loeb 2: 261).

[145] "oratio." It may be his Latin style that caused Cardano to describe him as "plebeian"; Granger, the Loeb translator of Vitruvius, remarks (Loeb 1: xiv): "The Latin of the mason's yard and the carpenter's bench and of Vitruvius's textbook was to be echoed all over Western Europe in the early part of the Middle Ages."

their own language for common use, the patricians speak Illyrian,[146] the learned write and translate Arabic. The Jews too have the language of the region they inhabit, and their own, which is Hebrew. And we have Italian, distinct from Latin, and another more refined, which we call Tuscan or Etruscan—so that individual nations now no longer have two but three languages; the Romans too, as I said, in place of the popular, and the patrician language, which was to them what Etruscan is to us, used to have Greek instead of our Latin language. And the ancient Greeks had a popular and a refined language; instead of an external one, there was another kind of language, which anyone who reads their poems will notice.[147] Africans too have a triple language; besides the refined one and the popular one,[148] a proper African one, in which Leo Africanus states that a number of books survive translated out of Latin, which are missed by Latin people[149]—I do not now call that language proper African again, but I call it Arabic; it is accepted that very many works by Galen and other Greeks have been translated &852 into the Arabic language, and we are without them.[150] And a part of these (though a very small one) remains with us, without a Greek original. Many have perished through carelessness, others too are preserved in remote places. Münster[151] mentions that in a monastery of the city of Fulda[152] in Germany, near

[146] The Illyrian languages were Indo-European languages used by the Illyrians in the western part of the Balkans in pre-Roman times, but appear to have declined even by the Middle Ages, in competition with Romance and Slavic tongues. More on the remnants of the language is available in Anton Mayer, *Die Sprache der Alten Illyrier*, 2 vols. (Vienna: Österreichische Akademie der Wissenschaften, 1957–1959). However, what is meant here is Turkish / Arabic diglossia in the Ottoman Empire, along with Persian for refined poetry.

[147] B. F. C. Atkinson (*The Greek Language* [London: Faber, 1931], 164) notes that Attic Greek was "doubtless best regarded as the dialect of educated people." Others included Aeolic, Ionic (Homer's language), Lesbian (used by the poet Sappho), and Boeotian (used by Pindar). See now G. C. Horrocks, *Greek* (London: Longman, 1997), 21–31.

[148] In North Africa Arabic has long been much in use, and possesses classical and colloquial forms. In addition, the Berber language has a number of dialects spoken in various parts of North Africa.

[149] Leo Africanus (*History and Description of Africa*, 1: 165–67) discusses mainly the question whether there ever was an African (not Arabic) alphabet, and does not actually make the statement here.

[150] See D. Gutas, *Greek Thought, Arabic Culture* (London: Routledge, 1998), 91–93, 119, 128, 149.

[151] On Munsterus see n. to Book VII at 468 (1560).

[152] In Hesse in Germany, about 90 km NE of Frankfurt-am-Main. Münster (*Cosmographia*, Book III, 706) wrote that at Fulda there was a library of great age, some 700 years old, and there they showed Charlemagne a small book on the perpetual maintenance of the Catholic mode of worshipping God, imploring him to protect this practice. St Boniface's body was buried there. See J. E. Raaijmakers, "Sacred Time, Sacred Space:

the principal church, which houses St Boniface, who converted the Germans to the Christian faith, there is a library set up by Charlemagne seven hundred years ago with every kind of book, and it still survives.[153] Thus there lurk everywhere monuments to great men, which are preserved in languages, sometimes not the native languages, sometimes not their own languages either. The Germans have the same threefold use of languages that all the others have too. Nations differ not just in their marks for reading and writing and speaking, but in their ways of writing: Latins when writing move from right to left, Hebrews from left to right,[154] the Cambaiensian[155] Indians from above down. No other ways of writing can be developed, unless someone wants to do it obliquely.[156]

Among[157] all human actions it is very difficult for two movements to stay contrary at the same time—for example, while raising one's hand to lower one's foot; to blow breath from one's mouth while breathing it in at one's nostrils, as the Muscovite flute-players regularly do. Lyre players do one or the other; doing both is established by practice;[158] this last feat commands admiration, to see the flute player inflating his cheeks all the time, and it is very useful too, because it can be diverted for instance to divination, and attracts much profit.

We usually &853 call the following people maimed—the blind, the deaf, the squint-eyed, the limping, those with six fingers, and such natural monsters, that are endowed with evil ways of life. Astrologers very readily settle the problem, saying that witches are in charge, from whom a cesspool of crimes takes origin. We will put it that nature has erred in the easier feats, and therefore has failed more truly in the most difficult ones—and so, as all maimed people are inferior,[159] yet not all with faultless bodies are of sound morals; it takes more to shape a faultless mind than a faultless body. So worst of all are the hump-backed, since the error lies round the heart, the starting-point of the whole body. Next

History and Identity at the Monastery of Fulda (744–856)" (Ph.D. diss., University of Amsterdam, 2003)

[153] In fact Charlemagne's will directed that on his death his library should be sold and the proceeds devoted to good works. B. Bischoff (*Manuscripts and Libraries in the Age of Charlemagne* [Cambridge: Cambridge University Press, 1993], chap. 3) seeks to reconstruct the contents of the library, and concludes that "the fate of Charlemagne's library is shrouded in darkness, as is its origins and life." Thus its transfer to Fulda cannot be confirmed at all.

[154] Cardano has transposed these!

[155] On Cambaia see n. 19 above.

[156] "transversim"; this means "crosswise" or "transversely," but presumably Cardano meant to suggest obliquity.

[157] This paragraph first appears in 1560.

[158] "ut alterum citharistae, vtrunque usu constat." At a guess, the meaning is that the lyre player strums, first one way then back again; the skilled flute player can exhale by mouth while inhaling by nose at the same time.

[159] "improbi."

come the blind and the squint-eyed, because nature has gone wrong round the brain. Then the mute and the deaf, as nature has failed in a less important part of the brain. Then those who limp, and after them those who are damaged in a major limb; next those with six fingers and who have webbed fingers—nature has deviated in less essential respects. The last position is for warts, and traces that imitate scars. But even natural warts can be destroyed with oil of vitriol. It also makes a bald patch, if you smear it first with oil, then moisten a cloth with a lye[160] in which lime and orpiment[161] have been heated and dissolved. This medicament can destroy hairs at their roots, and unless you block it with oil (as mentioned) or if it sticks on for rather a long time, the medicament strips off the skin. The same is achieved by the first water of distillation of gypsum and by crystallised salt;[162] the latter is more stinging. Very acid distilled vinegar removes the scars of smallpox and blemishes resembling freckles; the place should be &854 washed next day with water in which bran and mallow have been boiled.[163] But now that I have come to mention adornment, I must speak of what helps towards beauty. There are three headings for this: either to preserve the [567; sequence has omitted 565 and 566]natural beauty, or to adorn it, or to add attraction with pleasant perfumes. Reconsidering the items is not in our present plan, but belongs to the books *De Rerum Varietate*.[164] First, the teeth are cleansed of stains with tartar converted into water[165] while it is kept in a marble vessel. This is prepared from the first water that drips from the distillation of saltpetre[166] and alum. The teeth are cleaned gradually if they are rubbed persistently with a root of mallow. And that is an excellent thing, because its softness prevents it corroding the gums, and it purges the teeth with its roughness, and has been tested. A crust of bread is burned enough to turn to charcoal, and is then crushed and the teeth are rubbed with it, and are washed with clear water. Though many agents are more odorous than it, celery is as good as anything as a remedy for foul mouth; is this because apart from the extent of its odour which masks the bad smell, it

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160 "lixivio."

161 See nn. to Book II at 196 (1560) and Book V at 384–85 (1560).

162 "salis gemmae": On this phrase see Theodore Zwinger's *Compendium medicinae universae* of 1724 (available at http://www.uni-mannheim.de/mateo/camenaref/zwinger/zwinger1/bd1/zwingercompendium1-toc.html, accessed on 24 Feb. 2008) which remarks that "Sal Fossile alio nomine vocatur Sal Gemmae, quia sub gemmarum forma eruitur e fodinis. Aeri expositum insigne acquirit gravitatis incrementum. Efficacius est Sale communi, et egregium diureticum." So it is salt as a mineral, crystalline NaCl.

163 The material from here to the penultimate paragraph of this Book first appears in 1554.

164 First published at Basle (Heinrich Petri) in 1557. For details see Maclean, *De libris propriis*, M104 (94).

165 "in aquam mutato"; presumably the tartar was deliquescent and took up water vapour from the surrounding air, so as to become a fluid.

166 "halinitrum."

powerfully breaks it up and weakens it, and it sticks a good deal because of the fattiness of its moisture? But for removing blemishes on the face we use tartar, and washings with mallow water in which wheat bran has been left. Agents that produce brightness and a sheen are made from white of egg, egg sweat, or mallow flowers, also sugar. Also, what is bright is of this sort, for instance sublimated silver;[167] but far better, and harmless, is talc, for making "fucus,"[168] if it is made, so to speak, "native."

To smooth the hands and &855 soften and whiten them, either ox bile with much water, or the refuse of the vessels that runs down from the martiacocta,[169] ground up like glass, or soap from palm oil; these cleanse the hands marvellously. Some people add ground iris root to common soap, others add shellfish shells, others cuttlefish ash; but these additions have been endorsed by test.

The agents that protect lips and hands from cracks, and soften them and make them sweet-smelling, are fats, and among that kind the perfumed and pure ones are those recommended for use. The technique is like this: crush and mix with fresh fat its own weight plus half of amaracum,[170] commonly called marjoram, or roses, or myrtle or galingale[171] leaves, and divide up into pastilles. Sprinkle it with neat wine[172] and store in a closed vessel in the shade for twenty-four hours (more or less). Then pour water over the pastilles and cook gently and sieve. Next, repeat with a half greater weight of the same perfumed herb (whatever kind it was); crush it, divide it into slices, and put it back in a clean vessel, keep it contained for the same number of hours. Lastly, gather the pieces, pour water over, boil, put back after sieving, adding perfumed herb once more. And while you have done this three or four times, and it has drunk in the perfume, keep the purest product, adding if you wish clove or crocus or musk or civet. The pieces should always be sprinkled with wine, an odorous one too, so that the fat drinks up the odour better. Alternatively, the fat should be boiled up &856 quite frequently with wine in which odorants have been infused, till it has taken up the odour; wine acts faster than water to remove the fat's own odour and to imbue the fat with the odour of aromatics, and it more effectively stops it decaying or turning rancid, which is as I said a special fault of fats.

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167 This is not silver but "argentum vivum," i.e. mercury, which forms "corrosive sublimate" on heating. A procedure for creating this is given by Cardano in Book V of the present work at 397 (1560).

168 "Fucus" is a seaweed, and a dye from it was incorporated with talc in a kind of rouge given the same name; see Book V at 398 (1560).

169 A mixture of sand, alum, and other ingredients such as lead, suited to create a glaze on ceramics. See n. in Book VII at 477 (1560).

170 "amaricum" in 1560, but the original Greek is ἀμάρακον, a word for marjoram.

171 See n. to Book VIII at 555 (1650).

172 "merum."

Of this kind is the assembly of cosmetics called lip salve,[173] which softens hands, prevents wrinkles and cracks in them, as well as in the lips, and provides a pleasant odour. And it drives off scabies,[174] especially if a one-third part of styrax[175] (which is called liquid) is added. And overall it is well suited to all the faults of the skin, and hence in great use among the Italians. Its composition, which is exceptional, is as follows: deer fat, or that of a female piglet, a quarter part, and the same amount of stag's marrow. Mix. Some replace the stag fat with kid's fat, others leave out the marrow. Clear these of all refuse and skins, wash with white wine, and squeeze out repeatedly till all the wine and any impurity is removed, and the fat stays sound and dry and very pure. People add to two pounds of this pure fat eight or ten pounds of the cleaned crushed flesh of Appian apples,[176] and half an ounce of thin cloves, a quarter ounce of nutmeg, six grains of Indian ear of corn, four pounds of best rose water; they boil it all over a slow fire in a covered vessel, till nearly all the water is used up, then they catch the strained product in a vessel repeatedly washed out with rose water, and afterwards add four ounces of pure shiny white wax, &857 six ounces of sweet fresh almond oil; it turns liquid, and after straining it is all caught in a clean vessel, and purged repeatedly with rose water. To get it finally collected, the rose water is repeatedly stirred and mixed for a long time with a wooden pestle after the addition of the musk and the other perfumed waters, till it drinks in a very delightful odour, and is put away in a glass vessel in north-facing shade and preserved. These serve as samples of items that serve cosmetic purposes, since we spoke a little earlier about removal of hairs, and so let us return to our planned sequence and talk about the cases in which nature goes further astray than in the maimed.[177]

These are the monsters.[178] There are numerous kinds, and they are not classed in species, so that they are of unlimited species. It is said that in Cracow[179] an infant was born with a proboscis in place of a nose, with rounded and winged eyes, ass's ears, another two eyes above the navel, the tail of a mouse,

[173] "pomata."

[174] This word covers various forms of eczema and scabby itchy affections of the skin, as well as the skin infestation now known by the word.

[175] An aromatic gum derived from the tree *Styrax officinalis*.

[176] This variety of apple is still cultivated in Italy. For details see http://www.unitus.it/dipartimenti/dpv/SITO_VECCHI_MELI/appia.html. Accessed on 24 Feb. 2008.

[177] "mutilus."

[178] Cardano was a connoisseur of monsters, and returns to the topic in his *De rerum varietate* (*OO* 3: 160 onward; Maclean, *De libris propriis*, M104 [94]). Ambroise Paré (*Of Monsters and Prodigies*, in *Workes*, 961 ff.) also listed a number of monsters, and mentions (1003) that his friend Gesner had received from Cardano a monster with a bear's head and the feet and hands of an ape. See also Daston and Park, *Wonders and the Order of Nature, 1150–1750*.

[179] In Poland.

but forked, and so long that it reached above its head, hands and feet with sets of four digits, precisely like the digits of a hawk, but they were joined by three membranes like those of geese. Under the armpits and within the elbows and above the knees individual dogs' heads protruded, to make six in all.[180] It is said that such a horrible monster survived for three hours, so that there is little need for surprise at what Pausanias says: that in his day women brought forth monsters much more horrible than the Minotaur.[181] But what is remarkable is that he referred to these as going to survive; the Minotaur, if not in fact a fable (as I &858 rather think), is supposed to have survived into adult life. Sebastian Münster[182] records that in Moguntium[183] [568]in our own time two women happened to be talking together, and one was pregnant. Another woman came up at a run, and banged the heads of the talkers together. When the pregnant one gave birth, she imprinted the signs of fear on the babes; in fact she produced two girls, joined at the face from the top of the forehead to the nose, so that they could only look sideways. This monster still survived to the tenth year. Another case, of a girl, was dead, and after being cut free of a living one, that one died too—it is not clear whether this was from fear or shame or from the mental distress that the poor thing had suffered while the other was sick and wasting away. What is quite certain is what many people have frequently suspected, that the condition of pregnant women can damage fetuses in the womb. This explains so many patches on infants of port wine colour, pigskin, pomegranate-like skin and the like. For when the mother of these girls was stricken with fear and held the image of the crushed head, the girls' heads coalesced into one; I would not actually have believed that this was the work of the crushing alone, although it contributed significantly, since quite often women strike their belly with a greater impact than on that occasion when she struck her head, yet twins do not combine—if the collision was the only cause of this, it would not be just of the head, but while the head is being struck, of the back or the belly.[184] It is agreed that among monsters only the one has survived that had the middle part of a boy fastened on &859 below the navel, so that it could usually urinate through the boy's penis. This monster used to wander about, a young man of twenty-five carrying it in front, the interpolated part of the boy being like one of ten years old, whether you looked at its legs or its feet.

This[185] year we saw another from Germany, very like the previous one, age around twenty-five, sex that of a young man but uncertain; a male infant hanging

180 On monsters see A.W. Bates, *Emblematic Monsters* (Amsterdam: Rodopi, 2005).

181 Pausanias, *Description of Greece*, 1. 24. 1.

182 On Munsterus see n. to Book VII at 468 (1560). Reference not traced in Münster's *Cosmographia*.

183 Mainz, in Germany, on the Rhine below Mannheim and above Koblenz.

184 The sequence of thought is not quite clear here.

185 The next four sentences first appear in 1560.

down (he urinated from a penis), arms and hands and legs shrunken, but only the legs of fetal size, the rest being what we have called very slender, no anus nor perineum,[186] buttocks fastened together like a leather bag. It ought to lack the power of sensation, for if a complete animal is deprived of its head, it must lack both movement and sensation. But if the animal had possessed the soul of a woman (its face looked closer to a woman's), as a perfect animal it could have moved, by more than four indications. But Aristotle, and we ourselves elsewhere, have shown that this is impossible; however, nothing prevents parts moving separately, as fingers do. There are therefore many questions on this needing explanation from us. First: why do most monsters live while in the womb, but die after birth? Then, which monsters can survive and which do not? Further: in generating monsters, does nature preserve some purpose? Is the deviation and abandonment of due order and potentiality always of no use? And are monsters what their name indicates by its derivation from "showing,"[187] and do they always presage something to come?[188] Finally, why is it that when the fertility in Egypt is greater, human virtue more vigorous, and the air better, yet monsters are &860
more common? Arising from this: what are the regions and the reasons for the generating of human monsters?

At the start, the monsters live very easily in the womb and are brought to completion, since they are generated, and what is generated must be preserved by the same causes too by which they come into existence. But since they have departed from their own nature and are weak and most unhealthy, they die as soon as they are born. As offshoots[189] they live in association, because creatures generated together share in the life of those with whom they were generated; it is much harder to live in isolation than in association; so when born, what was alive in the womb dies at once. There is also another plan:[190] when they start being generated, they do not quite conform to the generation of perfect creatures; for instance, when a lettuce and an oak first start sprouting, one can hardly be distinguished from the other; when they are brought to completion, they are so different that no one could fail to distinguish them. And when lines start from the same point and are very close, they separate more the further they have gone. Accordingly, when creatures are in the womb, being less far from their starting point, they also diverge less from their natural form and make-up. Hence the more a monster grows of itself, the weaker it gets, and the closer to death. Once

[186] "interstitium." But the word, though apt as indicating the perineum, is not indexed in Vesalius, *De humani corporis fabrica*, nor given this meaning in Castelli, *Lexicon.*

[187] "monstrando." "Monstro" is descended from "monere," to warn.

[188] Daston and Park, *Wonders and the Order of Nature*, 177–90, provide instances of monsters as prodigies presaging ill in the 16th century. They also (164–70) discuss Cardano's general interpretation of wonders.

[189] "adnata."

[190] "ratio."

born, it encounters chillier air, and so monsters live longer in hotter regions, for instance in Egypt; less long in Italy, for these reasons, and much less so in Germany. There are monsters alive that have departed less from their natural state, and done so less in their more important organs[191]—&861 this is why a two-headed monster has never survived long. And as mentioned, they survive more easily in warm air than in cold. Of those that survive, the more appropriate their form, the longer they live. And the size by its position, and the position by the form, and the form by number depart less from nature.[192] And since they have departed from the human form, the more they have departed from it and towards the form of beasts and wild animals and fishes and snakes, the less long they live.

But why is the abortion of monsters uncommon? It is because abortions are rare, monsters are rarer still, so the abortion of monsters is very rare. And[193] a cause which has overcome the order of nature must be powerful, so as to be incapable of defeat unless a change has been made; therefore mothers will rarely abort monsters deliberately.

But now it is to be shown whether a monster is a simple error of nature, or is also at the time making for some aim, such as making a ram out of a human being; if it had absolutely no aim, what was being born would be formless—but it is not always formless. Some people, such as Aristotle, have felt that when nature deviates, it reaches its aim in the nearest kind—for instance, a female instead of a male, a biped instead of a human being, or if that is impossible, a quadruped from creatures that are more human, on the argument that it rarely begets fish, and never trees. But if this is so, it would generate birds[194] more often than rams. And when nature aims for a kind,[195] it must aim to shape some species of that kind. So when it cannot achieve some appropriate aim, apparently it constructs from the kind[196] the [569]nearer aim that is not undefined, with no resistance from the matter. &862 So when the matter has been of diverse portions, a multiform monster will be generated: when the matter is quite unusable, the monster will be totally shapeless. Hence those monsters that lack form altogether live with a life little better than a plant's, and die at once. When part of the matter has diverged moderately from its proper temperament, a small error develops in that part; for instance, a noble virgin in the women's quarters of the Prince of Luxemburg had a double bone instead of teeth, and attained nothing

[191] "membra."

[192] "Et magnitudo situ, et situs forma, et forma numero minus à natura recedunt." Meaning unclear.

[193] This sentence first appears in 1560.

[194] Which are of course bipeds.

[195] "genus."

[196] "genus."

else of note except an exceptional seriousness of life.[197] This commonly raises the question whether monsters always foretell something. Melanchthon,[198] a learned man, records that before the war that the Emperor waged against the Germans,[199] an infant was born in a Frankish community, and at once a sword was seen projecting from the womb of the woman who had been delivered, and could not be extracted before the womb suppurated. Melanchthon went on that this prodigy indicated civil war in Germany, because the sword was protruding from the womb and the viscera.

But why a sword? I think the material was hard, and of a colour like iron, since it could not be iron. But it is the business of the books *De arcanis aeternitatis*[200] to show whether such occurrences always foretell something. Prediction would be frequent in Egypt, since monsters are frequent. The reason is twofold: first, because women produce more infants at a single birth; hence very many infants degenerate from their proper nature and pass over into monsters, both through weakness and through the fetuses striking each other. Again, the monsters live very easily both in the &863 womb and outside, because of the healthy air, so that there they are born at eight months, and hence in Egypt more monsters are born to women and to the other animals. So the reason for the generation of monsters is the ease of generation, so that they are very common in plants, and next in the more worthless animals; next in the important and fertile ones; finally in the perfect and less fertile ones, such as the human being and the elephant, they are very rare. Additional reasons are monstrous intercourse, ridiculous imaginations, and perverse temperaments.[201] This is why such births are ascribed to the wrath of God, though erroneously. And monstrous people occur with distinction and perfection, whether they are called prophets or wise men, either because of the exceptional nature of the parents, or because of comets and

[197] "mores."

[198] Philipp Melanchthon (1497–1560), professor of Greek at Wittenberg from 1518, theologian, a prolific author, and organiser of education suited to Lutheran rather than Catholic youth. See also S. Kusukawa, *The Transformation of Natural Philosophy: The Case of Philip Melanchthon* (Cambridge: Cambridge University Press, 1995). This tale is in his *Initia doctrinae physicae* (bk. II, in *Op omnia*, ed. Bretschneider, 13: 354): " . . . natus est infans in pago quodam Francorum, cui exempto ex alvo matris culter iacuit in ventre, eminens cuspide extra ventrem, qui et paulatim facta suppuratione extractus est. Omnes iudicarunt bellum civile significari." N.B. Cardano's translation is inexact; the point of the knife (not sword) was sticking out of the baby's belly, and was gradually extracted as suppuration came on.

[199] This may be his campaign of 1546, when the Emperor Charles V split the ranks of Germany's Protestant princes by winning over Maurice of Saxony and defeating others. But in 1552 Germany was at war again, and Charles escaped with difficulty.

[200] See n. 107 above. This work on the *Secrets of Eternity* does address the question mentioned, but with somewhat equivocal results.

[201] "pravitas temperaturarum."

constellations, or preceding combinations of stars, or because nature has transferred the power of many organs into just one. The result is that these people are at times less able for work.[202] Both for this reason and because discoverers tire of discovery, it comes about that famous men leave behind them disciples greater than themselves in repute and works—as Socrates left Plato, Plato Aristotle, Aristotle Theophrastus. This lesson was taught by Christ too, when he said, "You will do these and greater things. The disciple is not greater than the master."[203] But since human beings are like drums, which are nothing if not beaten, when they are beaten (even if the human beings do not wish it) they draw attention to themselves—it is a good plan for anyone who wishes to be in some special group to consider everything and weigh it all carefully up. &864 Since the pupils of celebrated men behave as being otherwise well aware of these men's discoveries, the successors of great men are reckoned greater than the actual inventors.

Now all that remains at the end, as we have covered everything, is again to discuss the actual starting point[204]—I mean the heart. It[205] seems to be called starting point in many senses: either that of the origin, like seed, or of generation, like the primary arteries and veins which end at the navel, on account of which it is said that those who are flayed in Egypt as a punishment do not die till the navel has been flayed. And the executioner is not free to flay that part without permission, so that the condemned man can be tormented longer. So the reason for this is that as the flayed man has breathed out spirit in all directions, but not all together, he does breathe it out all together through the navel, because there the peritoneum is perforated because of the vessels of generation, and so when it is finally flayed, the man then gets weak and is killed off at once.

And there is a starting point for movement, as the brain is, or for generating, which is prior to the starting point for generation, as the testicles are. Then though it is mentioned in other ways, the real starting point and the one for everything is the heart; we are now to speak of it as meriting primary and greater admiration. The way in which it moves and how it jumps and palpitates in love affairs has been sufficiently debated. But this movement is natural; if it does not obey the will, it is not a voluntary movement; if the starting point of the functions does not flag, it is not violent,[206] so it is natural. But &865 one natural movement is simple, another is composite; it is dilated by its faculty and also

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[202] "ut hi minus quandoque opere valeant."

[203] "Non est discipulus super magistrum." Matthew 10: 24, Luke 6: 40. But the conclusion is strained: the other teachers, according to Cardano, had disciples greater than themselves.

[204] "principium."

[205] The following five sentences first appear in 1554.

[206] "violentus."

contracted by it,[207] it does not quieten down spontaneously—and in those who are feeble it contracts slowly, and contraction follows upon the good supply of sooty air—so it is composite. Then is it heat, or soul? It is better to call it heat, as an instrument, but soul as the prime mover, for heat cannot pull anything apart in contrary directions, but soul can.[208] Thus it is like heaven's motion, both because it is brought about by the soul, and because it has a return movement, and never stops, and is regular.[209] But the latter[210] is composite in its direction and impact, the former[211] simple; the former is not circular but from a centre and to a centre, the latter circular; the former alters in response to conditions, the latter is unaltering; the former is brought about by the midpoint of heat, the latter by the soul itself; the other differences between the two are the drawbacks of mortality. Furthermore, the conditions of the mind move the heart, and thus with motion of the instrument of the heart, the body has to move; thus the whole body is obviously changed just by the conditions of the mind. The actual conditions reach us through our senses, which now fall to be discussed.

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207 Galen (*On the Natural Faculties*, 1. 4; trans. Brock, 17) does mention that "there exists . . . a pulsatile faculty in the heart," but makes little mention of this elsewhere, being concerned with numerous other faculties of more significance in his eyes.

208 The heat here is an instrument to make movement possible (see E. Mendelsohn, *Heat and Life* [Cambridge, MA: Harvard University Press, 1964]), but soul is the prime mover, and so can make the heart expand then contract.

209 "aequalis."

210 Heaven's motion.

211 Cardiac motion.

[570] &865 Book XIII
On the Senses, What Can be Sensed, and Pleasure

When in the beginning we needed three things—the preservation of human beings, supreme happiness,[1] and the eternity of their kind—the power of sensation was assigned to preservation, the mind to supreme happiness, the power of generation (which could perpetuate &866 nature by propagation) to the eternity of the kind. These being three different features, their excellences too are of the same number: mind excels in the distinction of its aim,[2] the generative power in longevity, and the senses excel in a multitude of conveniences. They are in fact for the appropriate acquiring of knowledge and the safety of the mind and of their owner. So they need to be five in number: those that reach us are partly nearby and partly distant. Those that are nearby either reach us externally (and the sense of touch is set up for their sake), or are acquired internally (and as they are acquired internally only with our consent, it is enough to explore them by smell beforehand; once they are acquired, taste detects them). Things that are not touched but reach us are seen in advance by vision, so that we can take to flight when they meet us directly. But when they come from the side, they are compelled to move the air and make a noise, of which hearing is in charge. So it was clear that we and the more perfect animals need five senses; and if nature had established a sixth one, it would be of no use. And so there will only be five senses. Aristotle[3] sought to prove this, but

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[1] "beatitudo." The first five sentences of this book are a considerable revision of the version in 1550 and 1554.

[2] "Mens finis nobilitate":—translation speculative.

[3] Aristotle (*De Sensu et Sensibilibus*, 2; 437a21) says that there are 5 senses [they are sight, smell, taste, hearing, and touch] and notes that this doesn't fit the 4 elements. He lists (3; 439a7–8) the 5 sorts of sense object: colour, sound, smell, taste, touch. He addresses the possibility of more than five senses, having noted that certain small creatures can detect food without being able to breathe—in his view by using a variant sense of smell (5; 444b20–21).

employed general[4] assumptions. Though it seems clear from the theory of the aim[5] that there is nothing else in things apart from these five features amenable to the senses,[6] there is a great deal of ambiguity, in case there may be a quality unknown to us— for instance, the way that dogs detect their masters, though it seems to concern smell, may perhaps be something better and more prominent which it senses? Features amenable to the senses are common to all, and are &867 themselves five: size, number, motion, rest, and form. Vision alone grasps all these perfectly, because it required them in the light; touch does this less perfectly, because it is only needed to make them out in darkness, while our eyes are impotent; while they are doing well, touch is adequate to recognise its own detectable features.[7] And they are hot, cold, moist, dry, heavy, light, soft, hard, tough,[8] crumbly,[9] smooth, rough.

Vision is the most important among all the senses that detect the outside, because it distinguishes being further away, being more numerous, being more detailed, being faster, being under several distinguishing features, being more divine. Who hesitates to recognise afar off, when he is detecting stars? Because there is nothing that is devoid of light or definite colour, there are numerous things that are primary objects for both eyes.[10] In very great detail too, for no sense grasps such fine distinguishing features as vision does. Very fast, as the only instantaneous sense;[11] for an ear awaits the arrival of the sound, and the sense of smell needs breathing. Vision identifies more differences of colour, and all the common features open to sense, either doing this on its own, or else very much in comparison with touch. More divinely, being the sense which on its own is unaffected and untroubled by sensing, and which alone of the senses most closely resembles the intellect. And so it is no wonder if nature impels us to be afraid in darkness, as if we had lost a first-class leader. Thus it is not the blackness or the obscurity of darkness that makes us afraid, but this, that lacking the help of our eye we feel weak and exposed to every injury. Company shows that this is so, by soothing &868 fear, though the darkness and obscurity remain; there can hardly be anyone who is afraid amid numerous friends, even in the thickest darkness, and it is true that we are more frightened in unknown and unfamiliar places than in familiar ones. Thus eyes are a safeguard for so many friends and associates. For this reason nature has fortified only the eye with eyelids, so that like a king, it could not be made to work alone, nor to take a rest unwillingly, and would see

[4] "communibus." The following sentence first appears in 1554.

[5] "finis ratio."

[6] "haec quinque sensilia."

[7] "sensilia."

[8] "lentus."

[9] "friabilis."

[10] Reading "quae ambo oculis sunt obiecta prima" hesitantly, although all editions used read "oculi."

[11] "ut cum solus illicò."

what it wished as much as it wished, and would refrain if it disliked it. The ear, however, is forced to hear against its will, and touch is similarly forced to feel.

Three features indicate that the eye and the seeing of what is sensed[12] is of very thin substance: that it discriminates very finely; that the image of the seen thing resides in no subject—if it did, it would have its location mainly in air, and would therefore be torn apart by blasts of wind, which does not happen; finally, that it is greatly disrupted by sexual excitement, by the shedding of blood, and by anything that curdles[13] the blood. So the best thing in us is the most detailed.[14] This sense is located in a watery medium, since both light and illumination needed to be located in a transparent thing. But we said that air did not enter into a mixture, so it could reside in water alone. Spirits too, being so thin, would have been consumed in hotness or dryness. And dryness was not required to hold species and enable a judgment to follow, since light and illumination remain. But as sound does not remain, it ought to be preserved in sensation, for judgment to follow. This is why sound was located in a dry medium. So because the eye is established in a cold and wet medium, and the faculty of smell was established in a hot and [571]dry one and in &869 nearby places, those who see well and at a distance have a weak sense of smell, and those who have a good one usually do not see at a distance; so the eye makes use of illumination and colour.

But there are numerous kinds of colour. Aristotle divided them into seven, and annexes to them the same number of tastes, so that the very pleasing can match the very pleasing, the very distressing the very distressing, and the midway the midway. When we noticed that he had reduced them to seven, since he attaches no respect to numbers, we thought he had taken them from the number of the planets,[15] and we allotted the colours and tastes to the corresponding planets.[16]

Matt white/yellow	Sweet/fatty	Venus
Saffron yellow	Acrid	Jupiter
Scarlet	Bitter	Moon
Purple	Acid	Mercury
Green	Sharp	Sun
Blue	Salty	Mars
Black/sombre	Bitter/harsh	Saturn

12 "oculum esse ac sentiendi visum."

13 "cogunt."

14 "subtilissimum."

15 "è numero erraticarum sumpsisse."

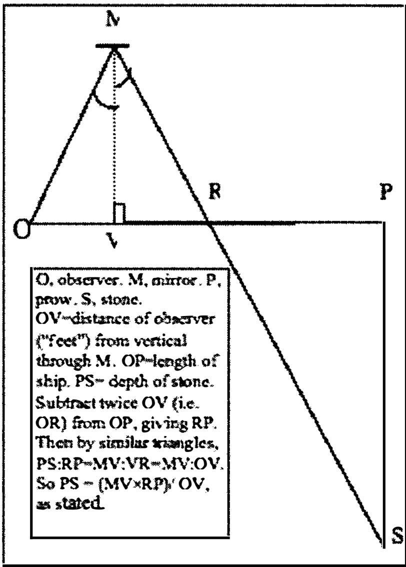
16 Aristotle (*De Sensu*, 4. 442a21–27; trans. Ross: 69) "If, as is reasonable, one reckons grey to be a kind of black, there are seven of each [colours and tastes], for there remain yellow—to be referred to white, as oily was to sweet—with crimson, purple, green, and blue intermediate between black and white; and all other colours are got by combining these."

But why is there not the same number of kinds in odours and sound and in qualities detectable by sense? There were more kinds among such qualities, and the sense of touch is not single—it appears to be fourfold. One distinguishes hot, cold, moist, and dry. The second recognises pain and pleasure. The third is the one that perceives the joys of sex, as we do not in any other part of the body sense a feeling of this sort, or any similar one. The fourth distinguishes heavy and light. And it perceives &870 rough and smooth, as also pain and pleasure—roughness is what induces discomfort, smoothness what induces pleasure; it is by reason that crumbly and tough are perceived. And so there are four modes of touching, and it is inappropriate just to allot seven differences to so many modes. In smell the particular qualities used to lurk, and their distinguishing features, because this sense is the weakest we have. But as sounds proceed from just one principle, and not from the four primary qualities, it was not possible to discover so many kinds among them. Thus it is clear enough why they are found only in taste and vision.

Learn of what the eye is capable from these two tests.[17] First: with a mirror you can measure the height and distance of a tower, and then the depth of the sea as well. Set up a mirror and look at the tower's top from it, and measure the separation[18] from your feet in forearm lengths.[19] Then carefully mark the mirror's position, and move away a known number of forearm lengths from your previous position, taking the mirror, displacing yourself enough to see the tower's top once more. Multiply the separation of the mirror's positions by the separation of the mirror from your feet in the second position; and divide what emerges by the distance between the feet and the mirror in the first and second position. And what comes out is the number of forearm lengths of the distance of the mirror in the second position from the bottom of the tower. With this distance discovered, multiply the height of your eye by the distance already found of the mirror from the foot of the tower, and divide this by the separation of the mirror and your feet in the second position, and what emerges is the number of &871 forearm lengths of the distance of the mirror in the second position from the foot of the tower. Example: let the separation of the feet and the mirror be twelve forearm lengths, and the position of the second mirror from the first be four forearm lengths, and then the feet be fourteen forearm lengths distant from the mirror, and my height be six forearm lengths. Multiply four (the separation of the places of the mirror) into fourteen (the separation of the mirror and of the feet in the second position), and they will make fifty-six forearm lengths. Divide these by two, the difference between fourteen and twelve of the separations of the feet and the mirror—twenty-eight forearm lengths come out as the distance of the mirror in the second position from the bottom of the tower. Multiply this by six (your height), they become 168; divide by the separation of the mirror and your

[17] "experimentis."
[18] "distantia."
[19] "ulnas."

feet in the second position, which was fourteen; what will come out as the tower's height is twelve forearm lengths.[20]



We will measure the sea's depth in the same way: we put the mirror above our eyes so that we can see a stone from the stern which we reckon is vertically below the prow, we deduct double the distance of our feet from the vertical of the mirror, from an interval defined by the position directly above the stone's position and that of your feet, and what remains we multiply[21] by the height of the mirror above your eyes and which is extended, we divide the product by the separation of your two feet and the mirror, and what emerges will be the depth of the sea.[22]

Thus the eyes have powers such that we could choose from an infinite number two fairly simple examples: but every sense especially enjoys what it recognises. What is recognised in hearing is the consonants, and in vision is the beautiful things. So what is beauty? A thing perfectly recognised by vision—we &872 cannot love what is not recognised. Vision recognises what is made up simply in the proportion double, triple, quadruple, one and a half times, one and a third times, as we have mentioned in connection with the human face.[23] So in the case of columns arranged on this basis, or trees, or parts of the face, when vision immediately grasps the equality and symmetry in them, it is delighted; delight resides in recognition, just as grief resides in failure to recognise. Furthermore, the obscure and imperfect is not recognised, because it is infinite, confused, and indeterminate; such things, being infinite,

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[20] The explanation of this may be that the mirror is lying flat on the ground and the viewer is looking at the image of the top of the tower in it. First he looks at it with the mirror at a distance x from its base and his eye 12 forearm lengths further away; then with the mirror at x+4 away from the base and his own eye then has to be at 14 forearm lengths. A pair of simultaneous equations can then be set up with unknowns x, and h the tower's height, and the solutions are h = 12 and x = 24, which agrees with the above.

[21] "ducemus."

[22] I am indebted to Professor Alex Craik for the diagram here, which assumes that OP is at sea level, by ignoring height of observer and deck, and that there is no refraction.

[23] In Book XI, 817 (1560). Commenting on this passage, Scaliger (*Exercitatio* 267 [811–12]) criticises Cardano for omitting the neck, "as if he were describing a fish"!

cannot be recognised; so the imperfect cannot give pleasure nor be beautiful. Thus anything proportionate[24] usually also gives pleasure.

The kinds of arrangement of pillars are the fruit of the same cause: pycnostylum,[25] systylum,[26] diastylum,[27] eustylum,[28] areostylum,[29] in comparison of length, thickness, with intervals and architraves.[30] What the eye does not recognise, at least lacks the proportion of small numbers,[31] and this reveals the whole undertaking as inappropriate, coarse and unrefined.

This was the advice of Vitruvius,[32] in the case of temples and their parts, to pass across the theory from the ears to the eyes. So in sexual attraction we look for beauty, nobility, and variety. As I have said, beauty attracts in itself, and in colours we look for purple and pink, a colour which is furthest from the extremes. Nobility is combined with rarity; we love what is rare more, since reaching these attractions is not easy—but we always strive for what is &873 forbidden, and want what is [572]denied. Variety and change and something untouched belong to the kind of rarity. And sometimes we are more tormented by the illicit, because achieving such aims is quite hard. Thus all our enjoyment lies either in what is lovable in itself (that is, is beautiful, or recognised by the eye), or in what makes us appear distinguished to ourselves; we appear distinguished in pursuit of what is forbidden to others, or is important, or rare, or untouched, or provided with a guard, or endowed with virtue, or illicit. Our mind is delighted with all of these, or a part of them, and rejoices, and obtains them even with the sacrifice of reputation, fortune and life. This is the cruel love, which I am going to discuss later. So men who can see sharply love less,[33] and not only less, but less often, because to careful inspection a perfect face free of blemish is a rarity, particularly because a smooth hairless skin and a rosy colour are sought after for beauty. So most men are in love because their vision is impaired, or they are in love before looking at what they fancy loving. This is why very many men are in love even against their will; they are forced into it in the presence of an image of beauty just like

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[24] "commensurae."

[25] Columns placed one and a half diameters apart.

[26] Two diameters apart.

[27] Wide intervals apart.

[28] Well arranged spacing.

[29] Narrow spacing. Vitruvius (*De Architectura*, 3. 3. 1—13 and 3. 4. 3) discusses the advantages and disadvantages of all these arrangements. See below, n. 32.

[30] "epistyliis."

[31] I.e. ratios such as 1 to 3, 2 to 3 etc.

[32] Roman architect and author of the earliest surviving treatise on architecture. Its range extends to hydraulics, acoustics, etc. He flourished about 90–20 B.C. I have not traced the passage from Vitruvius, though Books III and IV of his work deal with the architecture of temples.

[33] Burton (*Anatomy of Melancholy*, Part 3, sect. 2, memb. 5, subs. 3 [785]) quotes this remark of Cardano's with approval.

those who are seared by grief, and the power of imagination does not entirely comply with the will; and if you do imagine something beautiful, you are not free to withhold your love. So when a beautiful form is accepted into the power of imagination,[34] we are snatched away into love even against our will. This is why scholarly[35] people are more powerfully in love, because of the strength of their imagining faculty. And this is apart from putting it into action: and so for the same reason it comes about that &874 excessive love interferes with sexual intercourse;[36] the will draws in the spirits and recalls them to higher issues, and hinders the faculty of imagination, which is the greatest aid to sexual love[37]—it is a human characteristic not to attend to two things properly at the same time. But pathos[38] aids sexual love, so that sex comes easy to those who introduce force;[39] it expands and stirs up the spirit, and opposition inflames it, because the power of imagination is aroused. Erection[40] in fact takes place from imagining—for instance, when an attractive image is presented from the brain to the soul, the heart (where the soul dwells) transmits spirit and heat to the penis, exciting titillation in it through nerves from the brain. So while heat is making its way into it, it disperses the moistness on the route and turns it to flatus; with the insertion of this into the pumice-like flesh of the penis, erection at once occurs. This makes clear that the primary and entire soul is in the heart. And a warm heart does much for sexual desire. Hence the causes of diverse conditions are evident: in those whose erection is easy and prolonged, there is much concocted fatty moistness, but in those with easy erection and flaccidity it is thin. In those in whom there is more erection after earlier coitus, the colder part of the penis has been discarded; and this is what happens where the semen has been impaired through lapse of time. Because of slackness of the channels, in the elderly it happens that with the penis extended, flatus bursts out, with belly rumbling.

Tears flow in people suffering violence, because the heart and brain contract during grief with hope, and so the available moistness not only in the brain but also in all of the blood is squeezed out by the heat through the wellsprings &875 of the eyes. Horses and pheasants shed tears too, when they observe danger threatening.[41] But when hope is absent, no movement[42] or tear occurs. Therefore

[34] "imaginans virtus."
[35] "studiosi."
[36] On Cardano's own impotence, see n. in Book V at 370 (1560).
[37] "Venus."
[38] "commiseratio."
[39] "vim inferentibus."
[40] The following seven sentences appear first in 1560.
[41] Horses in the United Kingdom nowadays at any rate do not weep, even under stress. I am indebted to Dr Ann Lambie of Edinburgh for this information. But in the *Iliad* the horses of Achilles wept over Patroclus (17. 426–440).
[42] "motus."

in extreme terror or grief there is no weeping. So the poets have done well to describe Niobe as turned to stone at the death of her sons, not as weeping.[43] And tears of joy flow too, because in it too blood is moved outward with the impact. For this reason too some people have died of joy.

The eyes display all the conditions of the mind, and also the way of life—but especially joy and grief. In these, the ears are far behind the eyes, and so in these two circumstances are good for passing on instruction and arousing the states of mind.

The distinguishing features of sounds are of three kinds: high-pitched,[44] low-pitched,[45] and medium. Some are distinguished by fast or slow or medium; loud and soft and medium[46] proceeding from the size of the impact. But smooth and rough depend on the nature of the instrument. There are infrequent and frequent and medium, also discordant and concordant and medium. So of all the conditions that can move the senses, sound is alone in moving them maximally, because it is the only one with obvious movement. A loud, harsh, and energetic one, discordant, arouses people considerably to fury and battles, enough to make a man forget himself. So soldiers in battle, especially at the outset, do right to make a din with trumpets and drums, and to shout; it is indeed no small thing to risk one's death, and important people (or those disturbed in mind, which occurs particularly with &876 disorganised sounds and shouts) would only do this willingly for glory. And so Caesar was right to criticise Pompey for holding his troops back at the start of a battle, as if they were off to a wrestling match or to debate the minutiae of the philosophers.[47] Soft, occasional, small, and concordant sounds incline a person to pity. Soft, rapid, small, concordant incline

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[43] The tale of Niobe who was turned to stone when her children were murdered dates back to Homer (*Iliad*, 24. 604). For details of the various accounts see *OCD*, and Brumble, *Myths*, 244.

[44] "acutus."

[45] "gravis."

[46] "magnus et parvus."

[47] After the battle of Pharsalus in B.C. 48 between Caesar and Pompey, Caesar wrote (*De bello civili*, 3. 3. 92) "Pompey had ordered his soldiers to await Caesar's attack, and not to advance from their position, or suffer their line to be put into disorder. And he is said to have done this by the advice of Caius Triarius, that the impetuosity of the charge of Caesar's soldiers might be checked, and their line broken, and that Pompey's troops remaining in their ranks, might attack them while in disorder; and he thought that the javelins would fall with less force if the soldiers were kept in their ground, than if they met them in their course; at the same time he trusted that Caesar's soldiers, after running over double the usual ground, would become weary and exhausted by the fatigue. But to me Pompey seems to have acted without sufficient reason: for there is a certain impetuosity of spirit and an alacrity implanted by nature in the hearts of all men, which is inflamed by a desire to meet the foe."

to alertness. Low-pitched and medium at the end, and mixed from harsh and medium, also slow and small, incline to chastity and prudence.

It is surely a remarkable thing—though anyone can test it—that if a spear is set to touch a lyre, or a person's mouth as he speaks, if a person holds the rest of the spear's head in his teeth, then the sound is as if it were heard in the teeth; the person will hear voices and words far away, and he could not hear their sound any other way. Then see what sort of movements in the spirits create emotional states, and choose the sort of sounds for arousing these states. In fact people respond more uniformly to sounds[48] than to other things that can be sensed, because a sound is a very simple thing, and varies only in general distinguishing features. Tastes and smells and colours too proceed from the mixture of primary qualities.

Furthermore, there are three conditions[49] common to all things that can be sensed. First, as I said, they exist in proportion: such things are known, and therefore give pleasure; this is how it comes about that when twice (an octave interval) exists, this very greatly delights the ears; then twice an octave interval (four times), and after the octave another fifth (three times), then a fifth (one and a half times),[50] and afterwards one and a third times (the fourth).[51] The double tone[52] to one and a quarter times, and three times [573] &877 a half tone adds one and a fifth times, with an eightieth deducted, as I explained in my *Arithmetica*.[53] There are also six intervals of voices that consist in integral[54] proportions; one is the "supertripartiens quintas,"[55] the remaining one the "superbipartiens tertias."[56]

A second condition[57] is that everything in moderation is pleasing; there is none that is low-pitched and so large in the mountains of the Island of Hispaniola that it deafens people, nor is there one that is so soft that it wearies the

[48] "in sonos magis conveniunt homines."

[49] "conditiones."

[50] The string ratio of the Pythagorean fifth is 3/2.

[51] The string ratio of the Pythagorean fourth is 4/3.

[52] "ditonus," the major third.

[53] On this work's history, see Maclean, *De libris propriis*, M37 (64–65). But material about music has not been traced in the arithmetical part of the *Ars magna* (*OO* 4: 303–76) and the *Practica Arithmeticae Generalis* (*OO* 4: 14–195). Pythagorean tuning made all fifths perfectly consonant, and so all major thirds and major sixths are too wide by 22 cents (a modern measure, giving 1200 cents to the octave) = 81/80 = "comma of Didymus" = "syntonic comma." This follows from the string ratios: to the fifth (2/3) "add" (by multiplication) a tone (8/9) to obtain 16/27, which is very close to the ideal sixth (3/5), and the difference (by division, 3/5 x 27/16) is 81/80. Vitruvius (*De Architectura*, 5. 4) contains relevant information from the classical tradition, and Boethius, *Fundamentals of Music*, does so too.

[54] Or "complete" ("integer").

[55] 3:5, which is the major sixth.

[56] Evidently 2:3 (or 3:2) which is the major fifth.

[57] "ratio."

listener with listening. The same applies about the fast and slow, the high-pitched and low-pitched, the soft and (what is larger) the harsh. A third condition is that in all cases, what is better gives pleasure, and next comes what is worse; what annoys is the other way round. Thus there is light after darkness, sweet after bitter, roses after dill, concordant voices after discordant ones;[58] pleasure and delight, indeed, must reside in one of the senses, and every sense is associated with change, and change with contraries; so for instance there is change from good to bad, and this is grief, so delight will come from the change from bad to good, but the bad must be there first. Who gets pleasure from eating without hunger, or from drinking without thirst, or from love-making without lust,[59] or from making money without greed? Then the pleasure of gambling is so great because of the frequent alternation of losing and winning. Hence too the frequent repetition of pleasure. And in learning there is pleasure too, because we learn what we do not know. Is there then enjoyment in contemplating what we do already know? Surely either none, or less enjoyment than what occurs when we learn. We do not enjoy the prolonging of the action, because ignorance has not come first. &878 And the original action is an ignorance. So the poor appear to experience more delight than the rich and than princes, because they are subject to more grief. It is on this basis that the interval of a fifth in high-pitched and of a fourth in low-pitched sounds annoys the ear, and the other way round gives pleasure; a low-pitched sound after a high-pitched one strikes the ear and persists; therefore when there has been a low-pitched one that is simpler than a high-pitched one, it will give pleasure, but the contrary will annoy.

But we have already shown above that the fifth is a simpler concord than the fourth; on the same basis, the fourth above the major third is soothing to the ear, but when below it, it offends the ear; it is easier to detect one and a half times a fourth than one and a half times a third, because one and a half times a fourth depends on the "one and a half times as much."[60] So with sounds, as with pictures, what offends should be mingled with what delights, but in compliance with a twofold law: first, that what offends makes less of a mark on the sense of hearing than what delights; second, since the sense does not detect them, they should not be too precisely dissected. We said that a concord or harmony was a pattern of a number of voices, a pattern perceptible to the ear. If then they are so finely chopped up as to be imperceptible to sense, they not only fail to please—they even offend. So a picture of tiny flowers is neither appreciated nor gives pleasure, any more than such tiny lettering is. In these cases, as in the engraving of gems, a tiny error or slant makes them deformed; the sense of vision makes out the details by comparison—thus it detects large errors in great things, and small

[58] The rest of this sentence together with the following six sentences first appear in 1554.

[59] "tentigo."

[60] "sesquialtera."

ones in little things. In fact hearing recognises smaller differences than sight, and than &879 any other sense. In high-pitched sounds, it actually picks up very nicely one part in thirty-three— indeed, very nicely in eighty; it determines that a major third without that diminution is harsh, and that with it removed it is pleasing.[61] In distinguishing time, it divides a single impact into sixteen parts. So hearing is more subtle than vision, either because (as I said) its sense is the only one accompanied by motion, or because the objects of vision (such as colours) impair each other by their vigour, because of contiguity, or else because vision is concerned with many objects, but hearing with a single very simple object. And so increasing the impact and extending the time does much for the delight, as in the place of the "hemiolia,"[62] the only feature which in our own time musicians have recognised as a difference in time—a division extended into sets of five or seven parts. Since I have heard the latter only once, I have rightly adduced the former. Everything rare is valuable; since sound stirs the affections, the power in it is obvious.

I find two notable instances among many ancient ones, where sound had power to stir affections of the mind. The first is of Timotheus, who with a change of the musical mode constrained Alexander the Great to be induced by enthusiasm to burst out of a party.[63] The other is that when Agamemnon was about to set out from his fatherland and make for Troy, he had doubts about the chastity of his wife Clytemnestra (that is what she was called), and left a lyre player behind,

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[61] The Pythagorean third consisted of two tones, each with a string ratio of 8/9, and so had a ratio of 64/81. Removing the "comma of Didymus" or "syntonic comma" (see n. 53) by multiplying by 81/80 gives 64/80 = 4/5, the major third redefined in Zerlino's *Istitutioni Harmoniche* of 1558 (see H.F. Cohen, *Quantifying Music* [Dordrecht: Reidel, 1984], 5).

[62] "one and a half times as much," synonymous with "sesquialtera"—"That proportion which arises when three semibreves appear in the time of two semibreves, though more frequently three minims in the time of two minims. The sign designating this proportion is 3/2. Hemiolia is exactly the same as sesquialtera except that all the notes are blackened. The blackening of notes being itself a sign of sesquialtera, there is no need for the sign 3/2 in hemiolia. It must be understood that sesquialtera and hemiolia are identical in function . . . Finally, . . . Zarlino declared that composers introduced such intricacies into the notation of their music [simply] to show that they were not ignorant of the speculations put forward by the theorists of those days" (M. B. Collins, "The Performance of Sesquialtera and Hemiolia in the 16th Century," *Journal of the American Musicological Society* 17 [1964]: 5–28).

[63] This tale is in the *Lexicon* of "Suidas," 2: 1142, under "Timotheos"; the musician "made so powerful an impression on Alexander that in the middle of the performance he started from his seat and seized his [Alexander's] arms."

who used the sound of his lyre to induce her to chastity and continence, so powerfully that Aegisthus was unable to possess her before killing the lyre player.[64]

But the sounds that give the most delight themselves incline people to incontinence, while making them too keen on music. For instance, Nero did not neglect the care of the hydraulic organs that &880 bewitched him with their marvellous sweetness, despite risks to his life and power, defections of his armies and leaders, and his manifest imminent death.[65] These contain water, and air mixed through numerous pipes gives forth a modulation of the water mixed with a whisper. Vitruvius hands down the theory of these,[66] but it is agreed that his books were published after Nero's epoch, and I think it unlikely that these organs were so beloved by Nero, since they were built on such a well-known theory. And so my opinion is that the Vitruvian pattern should be reckoned more a standard[67] than a worked-out theory.

But it was not only the prodigal[68] emperor who was so pleased with musical instruments; David too, a very brave king and serious man, was fascinated by the sweetness of a psaltery,[69] and one calmed the mad Saul as well.[70] And it is not to be supposed that the harmony of this instrument is commonplace, since the

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[64] Homer however (*Odyssey*, 3. 265–272) does not say that it was the bard's *music* that kept Clytemnestra chaste: "At first she would have nothing to do with his wicked scheme, for she was of a good natural disposition; moreover there was a bard with her, to whom Agamemnon had given strict orders on setting out for Troy, that he was to keep guard over his wife; but when heaven had counselled her destruction, Aegisthus took this bard off to a desert island and left him there for crows and seagulls to batten upon — after which she went willingly enough to the house of Aegisthus."

[65] Suetonius, *Life of Nero*, chap. 41: "Even then he [Nero] made no appeal either to the senate or people, but calling together some of the leading men at his own house, he held a hasty consultation upon the present state of affairs, and then, during the remainder of the day, carried them about with him to view some musical instruments, of a new invention, which were played by water, exhibiting all the parts, and discoursing upon the principles and difficulties of the contrivance; which, he told them, he intended to produce in the theatre."

[66] Vitruvius deals with water organs in his Book 10, chap. 8; Loeb 2: 315–19.

[67] "modulus."

[68] "nepoti" in all editions used; the translation is a guess, since the word normally means a grandson, but can sometimes mean a spendthrift or playboy (*OLD*). But I find nothing in Suetonius or Tacitus to suggest that Nero was ever so described. An alternative is to substitute "Neroni" for "nepoti."

[69] In eight of the biblical Psalms of David (Vulgate numbers 32, 56, 70, 80, 91, 107, 143, and 150), there is mention of the worship of God with this stringed instrument. See J. W. McKinnon, *Music in Early Christian Literature* (Cambridge: Cambridge University Press, 1987), 180 (index listing "psaltery"); also 66, 97, 123.

[70] It was a harp played by David that calmed Saul, not a psaltery (1 Kings [or in the Reformed version 1 Samuel] 16: 23).

sacred page[71] so often recalls it, and since people have judged it uniquely suited for the celebration of divine praise. It comprises seventy-two strings, a precisely triangular shape, and its concord is incomparable.[72] We have also seen other instruments of remarkable attractiveness and workmanship, such as those that express the sound of trumpets, drums, pipes, reed-pipes,[73] lyres, horns, tortoise-shell lyre, phorminx,[74] syringa,[75] heptachord,[76] organs properly[77] so-called, and the sambuca.[78] The hydraulic organs mimic birdsong so well that you would have said it was a bird unless you saw it. Horns are closest to the human voice, with the addition of holes, [574]since long ago they summoned soldiers to &881 battle without these. So Vergil writes: "The horns clamoured their chant."[79] This is certainly crude music without a tune,[80] and more like thunder. Thunder emits a low-pitched sound, powerful and crude, so much so that sometimes it kills chicks in the egg and the fetus in the womb. And so this is what is especially at variance with music. However, it is not impossible for a concord to be created from several such sounds at a distance from each other, and this when heard is taken for a miracle.

But[81] in our books on *Music*[82] we have fully covered sounds and their effects. For now, it is enough to add simply that a sound becomes greater insofar as the

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[71] I.e. the Bible.

[72] This number of strings was not obligatory and could be much less. "A typical medieval psaltery would have a characteristic 'pigsnout' shape. This produces a double-sided harmonic curve, giving theoretically correct string length ratios to allow a scale to be produced using equal thickness and equal tension strings. There was usually a square section at the bottom, where the last few strings were of equal length, and therefore presumably graded thickness. This prevented the instrument being unwieldy—keeping the lower strings at equal tension would make them very long" (*Diabolus in Musica Guide to Early Instruments*, at www.diabolus.org). See T. McGee, "Musical Instruments," *Oxford Dictionary of the Middle Ages* 3: 1183–86, at 1184.

[73] "tibiae."

[74] Probably the oldest of the plucked-string instruments.

[75] A more conventional form of this word is "syrinx," the Pan pipes.

[76] A seven-stringed instrument.

[77] Reading "propriè" with 1554, not the "propriae" of 1560.

[78] Or sackbut; a kind of small harp.

[79] *Aeneid* 8. 2 has "crepuerunt cornua cantu" but the present-day reading is "strepuerunt," not "crepuerunt."

[80] "absque modulis." Only the 1550 edition speculates here that the cause of thunder is the sudden disruption of a cloud by lightning.

[81] This paragraph first appears in 1554.

[82] Begun in 1549 and later incorporated into Cardano's *De secretis*. "Cardano . . . was particularly proud of his contribution to this discipline" (Maclean, *De libris propriis*, M83 [86]).

clash[83] occurs with a greater impact; every sound arises from a clash, and is more high-pitched if what clashes is travelling through narrower places. The evidence is that if acorn cups are held in one's fingers with a part turned away, then when you blow strongly into them, they produce very piercing and powerful whistles—very high-pitched because of the narrowness of the place, and very powerful because of the impact. However, the narrowness of the place also assists the impact, so high-pitched sounds are audible further away[84] than low-pitched ones. But those that are generated spontaneously in the ears and are thinner than those of tinnitus are thought to augur[85] something—on the right, praise, on the left, condemnation: for some people this seems due to demons, of whom they report the thinnish voices, for others due to a keenness of the sense of hearing; this happens to healthy ears, with no hint whatever of disease. For others, to the so-called sympathy;[86] this power, which moves another person,[87] also moves the sense of the person to whom it is directed. But this does not happen always nor in every case.

&882 In importance smell comes nearest to sound, with its special property of either restoring or defeating ability,[88] because it spontaneously makes for the actual brain; neither sound nor colour nor taste nor heat nor cold are conveyed direct to the brain. So of the features that are sensed, smell alone is capable of killing or restoring a human being—the spirit in which the soul's work shines forth is either nourished by a good smell, or destroyed by a bad one. And so this is the reason why frankincenses are burnt ritually to the gods, because the divine part in us takes pleasure in odours. And this is also why it is regarded as an excellent omen, and an indication of the presence of some divinity, when a good odour is detected without a cause. And though other corpses stink, those of saints are thought to smell good, the power of their divinity battling against nature's decrees. But it is not impossible in accord with nature for a fresh corpse not to smell bad, as is told of Alexander,[89] or if it is ancient and well dried. As the corpse of some dead animals smells good, but the human temperament extends to a resemblance to each animal, it is clear that some human corpses can smell good; there is in fact a good odour either in a very dry animal or in the driest part of one. This is the more so because many bodies which are held in reverence are

[83] "collisio."

[84] "longius"—or it could perhaps mean "for longer."

[85] "Inaugurari": the word classically means "to take omens, or to consecrate for a priesthood," and so is moving towards the modern meaning of "to augur."

[86] On sympathy, see n. in Book XII at 83 (1560).

[87] "alium."

[88] "virtus."

[89] See n. at 524 (1560) in Book VIII. Alexander the Great became a major figure in the subsequent Christian tradition, as indeed he did in the Islamic tradition. See nn. in Book II at 241 (1560) and in Book VIII at 524 (1560).

usually preserved with balsam or aromatics or spiced ointments.[90] So this sense of smell appears to be the only one that is shared[91] between soul and body, and so it is passed across with vapours, as some things are by touch and taste, and apart from these is devoid of all matter, like things seen or heard. Hence we call those whose sense of smell is excellent, but &883 not their other senses, sagacious — for instance dogs and vultures.

Human beings who excel in their sense of smell are more gifted,[92] since a hot and dry cerebral temperament excels in sense of smell; such a temperament is quick at imagining, because of the heart, and clings to images, because of the dryness. There is no other animal that is delighted by a smell itself—only a human being; and even if dogs do detect the perfumes of flowers, they still are not delighted by them. They could not be, nor was it useful for beasts to take delight in taste or touch. What they needed was not to perish of hunger, nor to overlook reproducing, nor to avoid harm, if they were failing to detect pleasure and pain through taste and touch; but as I said, in other features capable of being sensed there could be no delight nor pain — because delight lies in acquaintance with the proportion of the actual features that are sensed, such as double, and one and a half times. But recognising these takes a loftier virtue than is present in beasts — so they cannot be grieved or distressed or delighted. It was also much less useful for them too: easily lured by pictures or sounds or smells, they would fall into traps.

The evidence is that deer, which just go limp[93] and are not delighted by the sound of the lyre, are exposed in this way to the wiles of human beings; and so are quails when the female's coo is imitated,[94] and so are small wild birds by other ones shut up in a cage. What a disaster their sense of smell brings to wolves and fish,[95] and they are wretchedly exposed to human cunning! But it would be more wretched to lack a sense of smell, because it was essential. So it would have been pointless for nature to provide beasts with a &884 delight in the other senses, of no use except to bring future disaster.

Cooks are right to add smells to tastes, because there is nothing special in them, but some of them are attractive when added to tastes, though not so on their own — garlic, for instance. Garlic put on victuals gives pleasure, but the smell is bad on its own, and after you have eaten it, it gives your breath a most filthy smell. In some cases this is even more so a day later, since with the passage of time thick substance generates an impressive array of quite thin vapours. Also, blood that is on its way to the lungs retains the smell, and the very excretions

90 This sentence first appears in 1554.
91 "communis."
92 1550, but not 1554 and 1560, speculates here that they also have poorer vision.
93 "stupent."
94 "simulata foeminae voce."
95 Evidently because they are caught or trapped by baiting.

smell of decayed garlic — also something from the stomach oozes through the gullet into the lungs.

For this reason it has been worked out that an odour is sensed only by tasting; it is not returned, nor causes trouble. This is what will happen if you disperse the garlic in vinegar, and rub it on plates, and discard its actual substance. This plan should be followed in the case of pepper and ginger and cinnamon, where the taste and smell of them delight you, but you are uneasy about their heat. But Apicius[96] has another method for these in his short account of running a household;[97] in this method the smell and taste persist, and half an ounce of cinnamon is enough for a whole year. Take odorous thin cinnamon, and cut it into slices of half an ounce's weight.[98] Put these back among twelve or sixteen peeled almonds, and squeeze; when these have been removed for use, put the rest away. And in this way at small expense everything you eat will be made fragrant with the odour of musk.

And if you want to add a taste, cook it into the food as if you were cooking in the tangy taste of mustard. This also &885 leads to very fast [575]cooking of vegetables and meat, and all the way to softening—it makes its way in with its heat and thinness, in which it excels, and it liquefies.[99] In a similar fashion, a spit made of juniper wood imparts a pleasing odour to all meat roasted on it; many people use wooden spits instead of iron ones. You should therefore notice from which woods your spits are made; where the taste and the odour is, there the powers will be. Thus it is clear that this and similar things make a contribution to health. But odours are linked to tastes not just by technique but also by nature; roast meat is at its best and should be taken out when it smells best; the smell signals the taste.

Some people take delight in a sharp taste, some in a salty one, so that "garum"[100] was used of old as much as anything. Its description is: guts, blood, and tuna gills are placed in a vessel and sprinkled with much salt; after two

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[96] Culinary expert who lived under the Emperors Augustus and Tiberius, though the *De Re Coquinaria* ascribed to him was probably compiled later, perhaps in the fourth century A.D. (*OCD*).

[97] "compendium rei familiaris."

[98] This does not make sense — a whole year's ration at one go? Perhaps what is meant is that the bits are squeezed with the almonds and then the almonds are used and the cinnamon recovered. No cinnamon recipe appears in the Roman cookery book of Apicius.

[99] The rest of this paragraph first appears in 1554.

[100] A fish sauce very popular with the Romans, chiefly made from salted mackerel guts. Scaliger in commenting at this point (*Exercitatio* 303(3) [907–8)]) refers also to "*Caviarum*," as salted eggs of Silurus (sturgeon), and says that teachers when he was young incorrectly called it "garum." Scaliger's view is supported by garum's etymological origin as a transliteration of the Greek γάρος or γάρον, with the same meaning as "garum," and without evident subsequent etymological link to "caviare." On caviare, see N. Fletcher, *Caviar: A Global History* (London: Reaktion Books, 2010).

months the liquefied product is poured out from the bottom. Another one is made from the guts of large fish, and also from little fish (especially Danube fish) too, pickled with salt. The ancients, as I said, used it with pleasure, and it benefitted their health as well, but now with us it is obsolete.[101] Someone[102] will wonder why some foods alter the taste[103] of a drink in the contrary direction, for instance bitter things — a drink appears sweet because of their action, and other things such as sharp-tasting ones do the same. But a drink does not appear sweet because of bitter things such as aloe, does it, and do similar odours always do this? For example, people talk of bread baked with pine wood; Julius Scaliger[104] wrote that it took the odour out of a drink, if he is to be believed. Since odours located on the tongue are assigned &886 from the drink to the sense of smell, with parts thinned out; moistness is more easily suspended in the breath than dryness. And those foods that impair the sense of taste convey a flavour like the affected instrument;[105] those that do not, present the image of delight from the resemblance to pain, as does a wormwood[106] drink arriving while a bitter taste is being washed clear.

Vinegar is created by the addition of salt and any pungent item that does not decay (I have tried pepper myself), and with great profit if pepperwort[107] is preserved. And it is created by fire; while it is boiling, then is put out in the Sun, and vinegar is already mixed in, it all easily goes sour. Another excellent recipe: Take cornel berries when they start to turn red, and brambles, and "centimora"[108] which grow in the meadows, while they are bitter. Pound them while dry, and collect in sharp vinegar, and mould into little balls. When these have been dried, they immediately turn wine into vinegar. The reason for this is that fire and the Sun make moist fattiness vanish, so that it turns sour, since its substance is thin; but if it is thick, it turns into saltiness, then into bitterness; this mixture is of an acid potentiality, in which heat is confined, and it makes whatever is fatty breathe away. On[109] this plan even putrid wine can be converted into vinegar. The corrupt wine is heated in a vessel and the foam is carefully removed, till it diminishes by one third; it is stored in vessels used for keeping vinegar, with the sort

[101] Further information about garum and insects and wormwood appeared here in 1550 but was removed in 1554.

[102] This paragraph appears first in 1560.

[103] "sensum."

[104] The remark about bread is not found in *Exercitationes* but may be present elsewhere in his works.

[105] The tongue.

[106] "absinthium," a very bitter substance.

[107] "siliquastrum."

[108] Not identified, although a plant named "centimorbia" was apparently known to Dioscorides but is not now identifiable.

[109] This paragraph first appears in 1554.

of additions I have mentioned commonly made to make vinegar, and thyme as well—this herb is well known, and sharp, and very suitable for making vinegar. Wild pears are so effective for making vinegar, that it can be made even from them &887 and water; the water itself, not just wine, is turned into vinegar, on Galen's authority. The method of making it is this: wild pears are kept in a heap for three days, then a little water is poured over them daily for thirty days. This may be repeated afterwards, for with the removal of the sweet part, the water passes across into vinegar, with the help of decay. Dates[110] and figs and grapes, with the sweeter juice squeezed out and water added—firstly and secondly wine is drawn off, and thirdly, very sour vinegar. And this has often been the experience. So vinegar is not made particularly from water, but from bitter juice while water is poured over it. For there are two parts in vinegar—the bitter and the acid; some of them arouse the bitter taste, some the acid, and some both. Both are aroused by a vessel impregnated with vinegar, which is uniquely excellent, and by vinegar itself. The bitter taste is evoked by bitter things, pepper, pepperwort, garlic; the acid by sour cornel-berries, wood pears and such things, also by any heat, such as that of the Sun, and fire; it makes its own taste breathe forth. Wherever pure earthiness like tartar[111] is mingled with the watery, an acid taste is created, as tartar is acid.

But if on the other hand you wish to prevent wine turning sour, suspend bacon from the lid of the vessel; by its fattiness and saltness it prevents separation and attenuation, which are the causes of the generation of vinegar. By the same technique, but not from the same cause, people simultaneously remove from wine and from the vessel the musty smell, by hanging medlars from the lid of the leather bag. &888 They are cut in four and stitched on a thread and let down into the wine for a month; and though people steadily insist that what I said ensues, I still failed to see this as I would like. A safer discovery and one on a definite basis is that if the unfermented juice[112] is placed in a vessel coated inside and out with pitch and tightly closed, and the vessel itself is sunk in a river for a month, it will stay sweet for a whole year, provided it was like that to start with—the wine is preserved for the future by the heat of the pitch, and the coldness of the water prevents it heating up, and thus prevents the sweet parts from being breathed off. It is from heat that the unfermented juice passes across into wine; so it stays sweet and cloudy,[113] and the white mustard mixed with the unfermented juice is preserved. A wine excels from three causes: either from its taste, or its charm, or its strength. In all these together there is nothing better than Cretan wine.[114] Next

110 "dactyli."

111 "faex."

112 "mustum."

113 The rest of this paragraph appears first in 1554, but see next note for a part first appearing in 1560.

114 The next two sentences and a little more first appear in 1560.

is what is imported from Spain; it is charming, fatty, smoothly thick, transparent, so odorous that it strikes upon the nostrils. It is healthy, and sound by nature, in such a way that it can even recall some unsound wines. But the dried grape of Crete is much more outstanding than the Spanish one; from their strength alone the pitch-flavoured wines of Greece,[115] which the Venetians call "Romania," are a great help for pains in the womb, not just because of the wine but also because of the pitch or the usual additives. The wine the Genoans call "lovable" is distinguished for strength and charm, and so is very good for the stomach. In taste and pleasantness, there is the white Florentine wine, which is called "Tribiana," and the pale yellow one of Lake Garda,[116] which is called "Vernaciola" or

"Vinaciola." To prevent them pouring out &889 while they are being drawn from a vessel, the [576]part D of the tube AD is inserted into the vessel, and A is solid; there is another rod, in which there is a narrow opening out of which the wine is carried along into the transverse channel B. Another tube is forced into B with an orifice F, receiving the wine from a narrow opening C, and releasing it below through the opening G; the slant removes the impact, so when it runs round F, as there is no orifice in the region of the opening C, nothing whatever runs out, since the pipe EFG is tightly inserted into B. How the vessels should be coated with pitch: melted pitch is poured into leather bottles, and shaken so as to stick all round. Then add a pound of Illyrian iris, an ounce and a half each of saffron and aloe wood, and

two pounds each of hyssop and nard ("pondo" and "libra" mean the same); they should be added before the pitch chills and solidifies, so as to stick to the pitch, but not while it is still very hot, as they would be charred.[117] This amount of aromatics should be placed in a vessel of ten-amphora capacity; the amphora's capacity is thirty-five[118] of our measure, and eight amphoras are almost equal to three of our brents.[119] An amphora contains eighty-one pounds[120] of wine in weight;

[115] Evidently the precursors of the "retsina" of present-day Greece. Resination was employed since antiquity.

[116] In northern Italy; "Benaci lacus."

[117] "urerentur enim."

[118] See n. in Book I at 37 (1560). If the unstated unit here is around 1 litre, the figures accord with the following note.

[119] "tribus brentis nostris"; in Switzerland and Italy, in the 19th century, the brent was a unit of liquid capacity approximately 39–76 liters, although that of Cremona was 147 liters (Doursther, *Dictionnaire*, 1840; see Bibliography). The next sentence indicates that one amphora contained 81 pounds weight of wine; a Venice pound weighed about 436 grammes, though other districts used different values. Hence one amphora's contents weighed about 35.3 kg, and assuming that the specific gravity of wine is unity, which will be correct to within about one per cent, the contents of eight amphoras weighed 282.5 kg and if this is equivalent to three "brents," they must have been large brents at 94 litres.

[120] Interpreting the "octuagintaunam libram vini in pondere" of 1560 as 81 pounds.

coating with pitch takes place annually, or at least every second year. And wines placed in a pitch-coated vessel, unless they are potent, pass over into flat wine.[121] That is why in our regions the vessels are not coated with pitch.

When wines are disturbed and before they are totally spoilt, make use of this expedient, although I &890 recall that I said much about it previously.[122] Two eggs, or even more, with the yolk if the wine is red—if it is white, from the white of the eggs only. Three parts of river stones broken up, two parts of finely ground salt. Mix five times over three days, or even more often daily, with shaking, and it needs to have been transferred into a clean vessel first. If any hope is left, this cures the spoiling; the yolk joins the sediment, the white joins the wine. With the white, other people combine lime and sand instead of salt and stones. It would also be better if as much honey as salt is added; these three things—honey, eggs, and salt—purge all liquids. The stone helps considerably with the drawing downward. In addition, experience shows reliably that acid cherries clarify, while making the wine warm up.

You can preserve fresh figs in wine for a whole year this way: after picking them without water and dew, put them in a new pottery vessel, so as not to touch each other. Put a square vessel on top, carefully closed with a lid, so that it floats on the wine, as will happen through the air held within; the figs will keep as long as the wine stays sound. It is obvious that the vessel ought to be thin, so that the thin part of the wine can preserve the figs—the moistness of the wine prevents them drying up. As the same moistness is not subject to decay, it prevents them decaying; indeed, as I said, we supply sound wine.[123] And if the plan is to harvest the early fruit from the tree during the winter, knock them down while they are small. Others grow to replace them, since the &891 fig tree does not produce a flower. Pomegranates and quinces and many other fruits of this kind are preserved by smearing on gypsum or chalk; when they are kept in a cold place, they stay sound because of the cold and dryness. Before they entirely reach complete ripeness, other people arrange them so that they stick to the tree on earthenware vessels, the vessels hanging from the tree, and they tie up the mouth of the vessel along with the tree branch carefully, so that air cannot enter, and let them be like that. But if the pomegranates are opening of themselves, three big stones taken from the bed of a river and placed on the roots, or a squill[124] planted nearby, will stop it.

The same squill guards all seeds from rodents—they avoid its sharp smell. And if the seeds you wish to sow are immersed in houseleek juice, it keeps the

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[121] "vappa."

[122] In Book V at 353–54 (1560) various procedures for cleansing and purifying wine are described.

[123] The following two sentences first appear in 1560.

[124] "scilla."

seed from corruption;[125] small animals and birds avoid its smell, as damaging, because it is a very cold herb. To get early fruit, water frequently with warm water, expose to the Sun, keep warm with pigeon and horse dung, or with lime for fruits that tolerate it, such as cherries, and gradually prune useless branches and anything of no use. But if you want late fruit, you will put them in the shade and keep them covered with plenty of leaves; prune fruit that is already started, along with the branches, before they ripen — they will flower once more, and produce other fruits — to bring these to ripeness, enclose them in winter in pottery vessels that hang from the tree. But if the plant is totally infertile, &892 Aristotle[126] advises that the root be split and a stone placed in it. If the bark is compact, the plant is made fruitful when the heat is tempered.

But if the fruit is rotting on the tree, or animals are growing in it, it is the result of plentiful moistness; so pierce the tree from the bottom, to serve the role of a blood-letting; all the superfluous humour will burst forth. Or else fix a fire-heated[127] nail in the same place — this expedient plays the part of a cautery.[128] Cherries rot easily, since they originate from a tree; strawberries rot with difficulty, as do cucumbers and watermelons, though they are herbaceous. But among the tree fruits, on the contrary, I sow pomegranates, medlars, service berries, quinces, because they are acid or bitter. Filbert nuts[129] quickly produce a worm, even though they are not seasonal[130] fruits. Hazelnuts[131] do not, nor do figs, though they are entitled[132] to be reckoned among the seasonal fruits. The cause of the decay is moist fatty crudeness; in trees, moist fattiness, but not concocted in all cases; the evidence is early cherries, grapes, and late figs. Hazel nuts, being seeds, produce a plentiful oil. All the herbaceous fruits are very unripe.[133] If fruit falls prematurely, a layer of lead wound round the trunk will keep them in place, since it does not allow over-plentiful moistness to get past. This is especially in trees that are nourished by the bark, not the pith. Most of them are nourished by both routes; if either some bark is removed all round, or if all the pith is extracted, almost all trees perish, especially fruit trees — some &893 later

[125] Translating "incorupta" [*sic*] with 1550 and 1554, though "corrupta" appears in 1560.

[126] "A tree that has excessively hard bark becomes barren; but if the root is split and a stone inserted in the cleft, it grows again" (Aristotle, *On Plants*, 1. 6; 812a12–14; Loeb, 179). These two sentences appear first in 1554.

[127] "ignitum."

[128] The following seven sentences first appear in 1560.

[129] "avellanae nuces."

[130] Reading "horaei" instead of "horarii."

[131] "ponticae."

[132] Reading "mereantur" for the "mereamur" of 1560.

[133] The rest of this paragraph first appears in 1554.

from the bark, as the fig does, others [577]never from the pith, like the willow. But this tree is not fruit-bearing.

If you intend to alter colours, insert into the tree a graft which bears a fruit of that colour. For instance, with a gourd[134] set in a mulberry, a red gourd will be produced, if the mulberries were red.[135] People think it was discovered on this plan how to produce pink apples: first by grafting a twig of the apple into a tree of red mulberry, then with the plant propagated by a succession of grafts. The evidence is that these apples have retained not only their colour but also their taste and small size. Then the same plan and the same specific advice apply to changing scent, taste, and colour. However, it is a good idea to nourish new plants with those that are alike in colour and perfume or taste; in every alteration, some trace is preserved of the one from which the alteration was made. Thus a process of change should be prolonged or intense—as trees do not tolerate an intense change, it has to be a prolonged one. Plants also visibly change in response to the regions or locations to which they are transferred—and with the location acting as food, or because of the winds and Sun. Also, damaged plants alter—in colour either way, and in taste and perfume rarely for the better, unless they produce bitter or acid fruit. And there are people who think that peaches planted under red roses get reddish, as if trees were altered by some sort of imagination, a phenomenon established in the palm tree, where the female is consumed with passion for the male, and wastes away.[136]

There are two trees that accept every kind of tree as a graft: the quince[137] and the wild fig, because their &894 nature is so kindly. And sometimes an olive tree is grafted into a vine, and this was noticed long ago by Varro via Macius Maximus,[138] and is called the "eleostaphylon."[139] Its fruit is like an olive carrying mixed with it the taste of a grape.[140] It is grafted on the plan I mentioned above, that grafting a vine into a cherry is possible—this transfer is more free from risk.

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[134] "citrium."

[135] The next seven sentences first appear in 1554.

[136] Pliny (*Nat. Hist.* 13. 7; Loeb 4: 119): "if the male tree, too, should happen to be cut down, the female trees, thus reduced to a state of widowhood, will at once become barren and unproductive." On sexual reproduction in the palm tree, see Book VIII at 522 end (1560) and note there.

[137] "cydoneum (malum)."

[138] Marcus Terentius Varro (116–27 B.C.) wrote works including *Rerum rusticarum Libri III*, and he (*Rerum Rusticarum* I. 40. 6–41. 6) discusses grafting, but does not say this. "Macius Maximus" has not been traced.

[139] Varro does not use this word; its Greek form ἐλαιοστάφυλος however is cited from the late treatise *Geoponica*.

[140] "acinus."

Some trees—peach, pine, and others with a stone—grafted into a willow are said to bear fruit without a stone, but I have not yet found this up to now. By planting branches divided in the middle like a vine-shoot, carefully removing the pith, and joining them up again, some people assert that one has been created without a stone, and the same in the case of other trees which are propagated by planting shoots.[141] For when seeds are generated in grapes from earthy matter, the stuff from which they take origin must be conveyed through the more rarefied part of the tree. That part is undoubtedly the pith; a fig has a more compact bark and wood, through which the juice passes. So if the plant survived the removal of the pith, grapes must be generated without seed; their matter cannot be transmitted through the compact substance of the bark or of the wood, nor through the empty gap left by the pith.

Consequently the grapes become smaller, with the loss of a part of the thicker moistness, and the bark becomes thinner, and the whole substance thin, as in raisins—it is in these that the most experience has been acquired, both because of the exacting care that is taken, and because there have been many trees that cannot survive without pith, and others only with difficulty. There are people who extract the stone from the outer skin as soon as it has opened of itself, &895 and wrap it in wool and then bury it.[142] This is how they say the Tarentine nut is created without an outer covering: it is surrounded with wool, in case the stone is eaten by worms, so that something else may arise.

But the most useful grafts are those of the peach into the almond and the grape into the myrtle. From one of these comes a peach with a stone of pleasant taste, and it is cultivated in Italy; from the other a pleasing perfume of myrtle is added to the grape taste.[143] And almonds are not esteemed only, as most other fruits are, for their taste, but also for their remarkable powers—they are believed to nourish the brain and the kidneys. People say that bitter almonds can kill foxes if they taste them. Athenaeus[144] and Plutarch report that the physician of Drusus challenged Germans to a drinking contest over his faith in them—if chewed beforehand, they are said to prevent inebriation; their dryness removes the thinner and more odorous part of the wine. Sweet olives[145] are fertile, and in food are welcome and very healthy.

If twigs of different bunches of grapes are cut through the middle and pushed down, but with the pith left in, and joined, they will produce fruit from the same

[141] The next five sentences first appear in 1554.

[142] The following sentence first appears in 1560.

[143] The following four sentences first appear in 1554.

[144] Athenaeus, *Deipnosophistae*, 52d; it was a physician at the house of Drusus, son of Tiberius Caesar, who beat all the others at drinking, till he was detected eating five or six bitter almonds before the contest. If not allowed to do so, he could not win. The effect was put down to their bitterness.

[145] Reading "oleae," the normal word for olives, instead of the "olei" of 1560.

tree and the same branches of different colours, and this is the case especially in the grape bunches, so that there are white ones, dark ones, and green ones. And it is not only grafts from elsewhere that alter the fruits of plants, but if the trunk is pruned and branches of the pruned tree are engrafted into it, fruit will arise far different from the original. In this way so many kinds of apples and pears have developed; any tree softens with grafting; wild plants are actually drier than domesticated ones, hence having a rougher bark, with more closely spaced (but smaller and &896 less attractive) leaves and fruit, also smaller, thinner, and more perfumed flowers; the whole plant is itself smaller, and better equipped with thorns, if of that kind.

Someone may ask why there are thorns on a rose. The reason is that it should be perfumed, and of a more stable perfume, and barely heating at all, so as to be more pleasing; cold perfumes refresh the soul more, because the brain is harassed by persistent heat, because of its motion. Since there was a flower, it was going to be of thin substance, and should therefore be linked to earthiness. So the rose's flower has earthy hot thin substance, otherwise it would not be perfumed. But if it was going to be like that, the whole plant should be like that, and of thicker parts, so that the flower would be made with the thin part detached.

But as the whole plant was earthy and dry, the earthiness had perhaps to be retained and get promptly dried out. But if it needed ejecting, it could actually be mixed with the leaves and have made them unyielding,[146] and then they would soon have fallen off, because of the excessive dryness. So the remaining alternative is the final one, and in action the better one: that this dry burnt-up matter, more or less the sediment of the flower, should be ejected outside.[147]

Since it could not have started to project from the rather hard bark unless it were spiky, the thorn has projected for this reason, and the more close-set and small it is, the more it instructs the rose to be more perfumed, thinner, and hotter—and also better suited for purging, and with a poor grasp of its perfume. This is what the wild rose is like, &897 whose flower is very often completed by five leaves; sharp, tiny, close-set thorns are even covering the actual leaves, so much so that you cannot get away with touching it, it is so [578]crammed with thorns. And domesticated roses have a flower with compact fatty leaves, with the result that the thronging leaves seem more perfumed, but the thorn thicker and scarcer and less sharp; the flower itself is better for flavouring the sugar and for water, because of its fattier substance.[148]

But[149] now that we have started discussing flowers, we must explain how flowers can be gathered throughout the year from plants (such as carnations) that

[146] "contumacia."

[147] Evidently to make thorns.

[148] But Scaliger (*Exercitatio* 303(8) [913]) reports that his own woman friends say the domesticated rose has less perfume.

[149] This paragraph in 1554 replaces material in 1550 on grafting.

are continuously verdant — this occurs in our town, and similarly fruit is gathered from the fruit-bearing plants. Getting flowers is reckoned harder than getting fruit, because trees that are continuously verdant have fruit all the time — for instance citrons,[150] oranges,[151] lemons, cypresses, and pine cones.[152] Flowers are available in these when the plants, kept in a rather warm place, mature enough to acquire strength at midwinter,[153] and a sort of ripe age; any plant flowers at a virile — or rather, a verdant — age, even if that occurs in winter. Also, the leaves and flowers are painted, as I have found — first with fig milk, then when the figure has dried or there are letters, colour is sprinkled on, or gold leaf, and they are wiped with a rag,[154] with the lettering or picture remaining. Some people assert that this can be done with any milk. This makes it clear that letters written in milk, though illegible on their own, still become visible from the trace when sprinkled with charcoal powder and wiped with a cloth. &898 The fatty part of the milk absorbs the colours, especially black, because of the size of the difference;[155] wateriness is absorbed so that it does not let the colours be diluted. This is why lettering is best written with milk, both on paper[156] and on vellum.[157]

To[158] get large vegetables and roots, such as leeks, celery, and many items of that sort, bury numerous seeds of the same kind in holes in goat dung, and then plant them — you will be astonished at the result, as soft shoots squeezed together grow in such a way that they take the role of just a single plant, and that is the experience. On the same plan, if you have planted seed of lettuce, rocket, celery, basil, and leek together in the same dung, a herb will grow that presents the taste and odour of leek, lettuce, rocket, celery, and basil all together. But if you want to add to fruit or vegetables the colour, odour, taste or the power of theriac[159] or purging power of plants, sink the seed three days before you sow it in something of that sort — for instance, for sweetness in concentrated new wine,[160] for a pleasant odour in ointment, for purging power in the juice of wood

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150 "medica mala."

151 "narantia."

152 "pineae."

153 "sub bruma."

154 "cotto"; but "mattress" does appear to be the meaning of this word in Book IV at 270 (1560), where see note. "Cote" would mean "with a whetstone." The sense here is unclear — but there is reference to secret writing.

155 "discrimen."

156 "papyrus."

157 "cutis."

158 A paragraph here in 1550 and 1554 concerned with degeneration of certain trees and vegetation into other kinds is absent in 1560.

159 On theriac see n. to Book II at 193 (1560).

160 "sapa."

cucumber,[161] against poisons in theriac—then it is planted, and nourished with such things initially. The task will be more effective and complete when during the insertion of the shoots you remove the pith and put such things in its place, and before you plant them you disperse the shoots in these liquors for three days. By this method it was found that if all seeds are perfused with saltpetre before sowing, what grows from them is more concocted.[162] Also, all seeds that are sown in squill produce more fruit, &899 as squill warms and moistens them, and the addition comes from the heat and moistness. For a special reason, a lentil submerged in ox dung is embedded in the ground.

Celery root turns out in proportion to the size of the empty space in which the seed was buried—not just in proportion to its length but also to its thickness; the growth of celery continues for quite a long time, and the plant is fatty and lively. In antiquity its leaves were enclosed in vessels so as to acquire a shape resembling their form. Hence I would surmise that in the regions where Theophrastus flourished,[163] celery kept its leaves all winter; it is a general characteristic of those that do not lose their leaves, like marjoram and basil among the herbs, and box and myrtle among the bushes, that they keep a shape corresponding to the form of the vessels or the arrangement of their fastenings.

Turnips too flourish to a remarkable extent in Italy, so much so that some are alleged to have reached a weight of a hundred pounds; they have a great deal of fatty moistness, for as mentioned elsewhere,[164] a copious oil is extracted, especially from the long ones. And those bitter roots which the Italians call "remolazos," offspring of a radish and a turnip, in which the taste of a radish is active and the size of turnips is retained—they grow to a huge size; I have seen five of them that reached more than twenty pounds weight, and others that were larger than a three-year-old infant. And the kinds get mixed—for instance, stems with the trunk of turnips are thought good to eat in Italy.[165] Leeks, too, with their leaves and &900 roots cut off are transplanted with a tile underneath, and as they cannot grow downward, they grow sideways and are called "bigheads."[166] The ancients knew them, because they were more attractive—more attractive because more tender; they are actually quite like onions. You will get toadstools[167] when

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[161] "cucumis sylvester"; apparently there is in Crete "Xylagouro (or wood-cucumber), a type of local cucumber which is very crunchy as well as juicy" (www.greeklandscapes.com/greece/crete/culture.html. accessed on 25 Apr. 2008).

[162] "coctiliora."

[163] He inhabited the island of Lesbos in the Aegean Sea. On Theophrastus generally, see n. at 80 (1560) in Book II.

[164] At 561 end (1560) in Book VIII it is stated that turnip seeds possess an oil.

[165] "Miscentur et genera, ut caules trunco raparum, esuique apti in Italia habentur."

[166] "capitati."

[167] "fungi."

a rainstorm comes on and the brushwood has not been burnt, or without a rainstorm if you sprinkle water on the remains of burnt brushwood. Alternatively, cut down a dark poplar tree, and pour water with yeast[168] into its fragments and along the trunk; the toadstools that grow like that cannot do harm. Toadstools are restored by a decoction of toadstools. Individual things (and especially those that are based in decay) are suited to generating their like. The damaging ones are wide and have blisters, and the reddish ones with sticky moistness that are readily scattered by finger touch, and those that are green when cut open, then the red ones, the dusky ones, the blue ones afterwards, and finally those that are dusky when a moment in time alters everything, so that anyone could be deceived by buried colours unless the toadstools are intact. And if you want to investigate more reliably, put it in milk, and you will see the flies die—so that use can be combined with experience.[169]

Of every other kind, the boletus mushrooms are safer, and those that grow on trees, and are rather long, with a thin wrinkled cap. It[170] is said that scanty solid saffron-yellow ones grow where truffles[171] develop, and are virtually their flowers, but underground; it is certainly accepted that those that grow like this are very safe and very enjoyable. They also grow on a sort of wide buried stones resembling tables; these are found in the Samnite area[172] four fingers deep in the earth, &901 and then water is sprinkled on for four days. They abound in woods, and come up quickly; they require rather a dry heat, so that it is a good idea for these stones to have something burnt near them. The generating of fungi is sudden, and virtually without any root—however, [579]nothing really generates without one. If in fact it draws in nourishment, if it is living, or grows larger even if not alive, it draws it in from the earth; and what is doing the drawing in ought to be linked to the source it draws upon; the part which is linked is the root.

Thus overall, the generating of all plants, and their enlargement, and their shapes and tastes and odours and colours and substances (and anything else there may be) take place through alteration of their places and of their nourishment, and through change of the seeds brought about by what is poured on them, and through conjunction with others, and pruning of portions, and fastenings or vessels,[173] and corruption of their substance, such as occurs with bruising and transplantation and grafting and prolonged propagation. Some plants are propagated from their like, some (such as fungi) from unlike things. The human race has cultivated these not for use but for appetite.[174]

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168 "fermentum."

169 "ut sit experimento etiam coniunctus usus."

170 This sentence appears first in 1560.

171 "tubera": truffles, or "tuberous roots."

172 A region in the southern Apennines (the mountainous central spine of Italy).

173 Both of these constrain the development of the plant.

174 "gula."

Thistles[175] can be eaten quite safely. They are globular heads covered with spines above on all sides, and these serve as the calyx of the flower, the source of the seed. A springtime treat at Paris and Venice, those without spines are less tasty. This is why they are not eaten by mice if sown among the spiny ones—the spiny ones are eaten. Numerous other kinds follow after this most important one, and so the whole year seems shared out among them; the smaller wild thistles come around the end of summer and in autumn, &902 but are the more tasty for that. Then at the start of winter and all through it, there are cardoons,[176] a bushy white plant, rather bitter, covered with spines—and not just the leaves can be chewed, but also the lower part of the stem and the top of the root (which is virtually bulbous). With the start of spring and up till summer, the wood cardoons find favour, not with their leaves (which are softly hairy),[177] nor with their root (which is hard), but with the bottom of the stem and the woody top part of the root. In nearly all the bitter plants, when the woody part sprouts out into leaves with an abundance of juice, it is gentle and less bitter, and retains the attractiveness of taste, but sheds the unattractive aspect of it. All these items, eaten with salt, vinegar, olive oil, and pepper, give not only pleasure but health; the salt concocts, and makes the taste attractive; in addition, the pepper enhances the odour; the vinegar breaks up the heat of all the rest, just as the oil breaks up the dryness, while contributing quite a lot in addition to the attraction of the taste.

A fifth kind of spiny plants is the Spanish oyster plant,[178] used for medicine, of no use as food. While all the kinds of spiny plants do the stomach much good, and purge the kidneys, and resist poisons, this particular kind of thistle does marvels for pestilent diseases, because it has a naturally split root.

A sixth kind is delivered from India and is called "Cerium," because with its straight and shiny white spears it recalls wax candles,[179] but it is of a size large enough to equal lances, and with a fruit no bigger than a nut, quite pleasant, red, full of granules. &903 There is also the "Pithaia" there, with a fruit like the eggplant[180] but of striking size, like what we call gourds or watermelons, which the Arabs call "bathecas."[181]

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175 "cardui." The next four sentences are modified in 1560.

176 "cardi"—related to artichokes.

177 "ob lanuginem."

178 "Scolymos," a kind of thistle with edible root.

179 "cerei."

180 "melongena."

181 The botanical term for a watermelon was at one time *Batheca arabica* (http://www.cavi.univ-paris3.fr/Ilpga/ilpga/tal/sitespp/13i01–0506/afchain-belouchat/exo%203.xml, accessed on 25 Feb. 2008). After this passage, 1550 included material on pine nuts, which is absent in 1554.

The last of the most important kinds of spiny herbs — one that India has too — is called "tuna,"[182] and its fruit extracts much blood with the urine entirely safely, and similarly it is of minor benefit to the stomach.

Olives do not differ much in taste from all these, but technical skill has discovered something to add: people shut them in the hollow of a panel[183] and beat them with wooden mallets, and push out the kernels; this is just how they are eaten at Genoa. It is remarkable how much better than olive oil olives turn out to be, a notable sign of exceptional dryness. Far and away the best of them all of the olive kind are the pickled onions[184] of Spain; they are extracted along with the twigs, washed in water, and dried for a day. Then they are preserved with salt below them and brine poured over them, as we explained earlier.

The moister fruits, such as pomegranates and pears and grapes, are preserved longest if gathered after a long preceding spell of fine weather, and cleared of spoiled grapes (if they are grape bunches), and scorched with the stem in hot pitch or (if there is none) wine. Then they are dried for two days in the sun, and arranged between straw so as not to touch each other; since all rot starts from watery moistness, as has been shown elsewhere, it will be necessary to remove this to prevent corruption of the fruit, and it is removed especially at the part where it is introduced — that is, at the stem.

&904 Watermelons are preserved by a different procedure: when placed in the sediment of sweet wine in a closed earthenware pot,[185] they stay unspoilt as long as the sediment does.[186] Watermelons and melons can be preserved differently, immersed in sweet unfermented grape juice.[187] And make no mistake in seeing that the juice stays sweet; if it does not, the melons get vinous. And if the plan is to have them early, sow them in baskets, and pour warm water over them, and keep them in a warm place, and in cloudy weather expose them to fire, in cloudless weather to sunshine; as they are particularly moist and lively, and flourish of themselves, fire does not spoil or burn them, but its power is blunted — power that in drier or less lively plants would damage and kill them. Thus in springtime they are dug out of the baskets with all the earth, and transplanted under the sky in open spaces. If their fruits are protected from the Sun and made safe from the winds, they can grow to a marvellous size.

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182 This word for a type of prickly pear probably originated in Haiti (*Chambers' Dictionary*), and so the "India" here must be the West Indies. 1560 supplies a revision of 1550 and 1554 here.

183 "tabula."

184 "Colymbades"; Pliny (*Nat. Hist.* 23. 32) says that they cleanse ulcers, but are of no use for urinary problems.

185 "dolium."

186 The rest of this paragraph and the first three sentences of the next first appear in 1554.

187 "mustum."

But if the plan is to keep them green through the winter, they should be sown near a well, and after they have ripened, they should be let down in the well near the water—that way they do not dry up, not being dried by the Sun nor shrunk by the winds, but turn green with the water's vapour and heat. But if the plan were for them to regrow, prune the unripe fruit down to the ground, then put earth over the actual plant and tread it down; the green roots and stems will re-establish fruit. The same system[188] should also be followed in connection with flowers in general. The rest of the throng that takes origin from vegetables—such as turnips, "cretanus," cress[189]—are preserved with vinegar alone, as I have found, but it helps to add fennel to all of them. &905 Others are better pickled:[190] gourds, skin of melons and bitter oranges, citron[191] flesh, whole nuts, and the lemon. They are macerated in water, which is to be diligently changed. They are cooked to get soft, and dried in the shade, then you pour over them honey or sugar cleared[192] by fire. After a week, remove and boil the liquid, and [580]pour it over. Repeat this three or four times; in that way they will become very sweet, and clear. I have said this already: they get musty if any watery moistness has been left over. Honey and sugar, and the rest of the juices, are cleared by white of egg and water, and by skimming and heating. It is said to be cooked, and is cooked, when a drop coagulates.

Fruits[193] are also preserved in other ways, as figs are: first of all the late ones, when those that fall from the tree and are unripe are ripened by cold. By "late ones" we mean those that grow when the earlier fruit has been pruned before maturity; the internal heat is concentrated and concocted by cold. Other items are preserved in liquids, as grapes are by vinegar; if you have added honey, it will not be ridiculous. I have actually seen those that look green preserved. Grapes are also preserved after virtual spontaneous cleansing in colder places, and they are hung facing north right till the Spring. Nuts are very conveniently preserved with honey; they turn out sweet, but the honey gets "arteriac";[194] it considerably benefits the throat. But the rationale for honey is a general one, as is that of vinegar and olive oil: the liquors that are preserved also preserve, unless watery

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188 "ratio."

189 "nasturtium."

190 "condiuntur."

191 "malum medicum."

192 "defaecatum." H. J. Cook (*Matters of Exchange* [New Haven: Yale University Press, 2009], 9–13) points out that sugar was rare in antiquity, in Pliny's time, but in the Renaissance the cane was imported to Venice and processed there.

193 This paragraph first appears in 1554.

194 No explanation of this remark is apparent, unless perhaps it refers to the trachea and means that honey comes to cause coughing. Paulus Aegineta discusses honey, but nothing visibly "arteriac" about it.

moistness is quite dominant. But vinegar ruins the taste, and &906 oil the odour; honey is better, being potentially hot and dry and fatty.

You can dry flesh that has not been completely cooked in summer, by carefully squeezing out the water for an hour in the shade in a breezy spot, and then sprinkling it with white vinegar and salt, putting it in a jar in a chillier spot, and turning it daily. This preservative technique will last ten days. Alternatively, when it has been cooked and dried like this, sprinkle it with salt and crushed juniper seed, and sink it into a jar full of white vinegar in a cold place, turning it daily. The attractive taste and odour will surprise you.

Items that are soft are not cooked when you want to preserve them, except fish; fish are mildly chilled in olive oil, and put away between leaves of laurel and myrtle after sprinkling with salt.

Laurel leaves not only preserve fish, but also rectify tainted water and make it harmless and smelling nice, and are an instant help against poisons. And lime rectifies it,[195] and also boiling, but laurel leaves are best.

Water is tainted especially by the same things as are tainted by it; such are wheat, and corpses, especially human ones; if they are more tainted by water day by day, they absolutely must taint water.[196] Lupins and flax taint it, so that in our town's ditch I was surprised by the throng of fish there killed in this way. Since on the whole there are many things that taint water, they can be classed in two kinds: either those that get tainted &907 in water, or those that are already deadly of themselves. But nothing is worse than for water to be at rest, just as there is nothing better than motion for cleansing it.[197] Yet motion is slow to cleanse water, but rest rapidly taints it. But if the water or wine placed in vessels is warm, sink these vessels in another quantity of water in which free saltpetre has been dissolved, creating careful movement; the water on the outside is cooled, since its vapours blow off as though impelled by some fire, but not so that others are created by the fire.[198] The quantity and method is like this: in a hundred pounds of water, take saltpetre up to 20 or 25 pounds. Pour in two out of three parts of this, and use a wooden male piston in the shape of a pestle to stir it little by little, slowly at first, then a little more vigorously, till as the chill increases it is stirred very fast, and always in the same direction. You will test frequently with your finger to see when it has reached the acme of coldness; then add the rest of the saltpetre, or a sixth of the whole, and stir till the water has reached the acme of coldness. When it has reached the acme, if it is stirred a little in the opposite direction, you will do no harm; but before that, much of the coldness would be removed. The dissolved saltpetre is condensed again by boiling the

[195] Tainted water.

[196] The next four sentences first appear in 1554.

[197] "Sed nil quiete deterius est, ut nihil ad purgandam motu." The translation is very elastic, in view of what follows.

[198] Practically all of the rest of this paragraph first appears in 1554.

water, and this has been done long enough when it solidifies on being poured out onto the pavement with a spoon. This is a more general and subtle scheme for chilling water, and wines sunk in water, yet all the same, water is better chilled by ice and snow. This is kept till summer's end in big pure chunks hardened by prolonged cold, &908 like those mentioned by Münster[199] as found in the ridges of the Valesian[200] mountains, hardened by many thousands of years; this region of Germany is so cold that the ice does not melt in any summer heat, but is dissolved by the heat of a fire or of the Sun, yet slowly. A chunk of this ice the size of an egg chills a large vessel of water, and fast too, as it does wine. He says he saw a kind of ice, fearful in its size and the fissures in it, which were so frightening that it could upset even brave men. And when it breaks, it emits such a huge discordant crack that the world seems to be collapsing. This kind of ice, and any other one, lasts longer the greater the time needed for it to freeze; the times for melting and for generation correspond to each other; the longer it takes to set, the heavier and more compact it is, and consequently also less liable to melt. This was shown in what we wrote about iron.[201] So chunks of it are kept for many days in shady mountain caves, or they are stored[202] among rocks and pieces of marble and straw, or between rock crystals[203] in a wine store open to the North.

I come to roots which it is intended to preserve, both the harder ones and the others, among which we choose the more tender ones. Those that need storing uncooked[204] are readily preserved by vinegar and pepper, also with the added perfumes of carnation and others. Be sure to bear in mind that some odours go better with others, also that human appreciation of them is not uniform, nor is it of tastes. But items we want to preserve with honey should be cooked &909 to a medium extent and dried, as they are softer and absorb tastes and odours better. This also makes them more delicious. With similar fine perception[205] man's industry tackles the skills involved in delighting the eyes. Hence our friend the bookseller Nicolaus Landrianus has imprinted images on leather in such a way that they look as though made from copper;[206] when he has moistened the leather a little, it is carefully inserted warm, with patterns[207] made of wood or other material. Wax is added to fill the void perfectly, and with paper pulled over,

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199 On Münster see n. in Book VII to 468 (1560).

200 Valais is now a canton of the south of Switzerland, from the Lake of Geneva in the west and including the upper Rhone valley.

201 Reference unclear and not traced.

202 Translating "condantur" ("are stored") rather than the "condiantur" ("are pickled") of 1554 and 1560.

203 "crystalla."

204 "cruda."

205 "subtilitate."

206 "cyprium aes."

207 "proplasmatibus"—classically, clay models for a sculpture.

the work is compressed between the plates of a winepress, and the part that is engraved is painted with [581]appropriate colours. It is part of the same exercise[208] to paint herbs to the life (as the phrase goes) on paper. A green herb impregnated with rust and ground charcoal on a basis of colour that highlights one or the other is embossed on paper,[209] so that the trace of a sort of ground plan[210] persists. Others would delineate the ground plan from a compressed leaf and small twigs, and then they represent a herb with herb juice and flowers with flower juice, but squeeze the water out of the juice, and add the gum they call tragacanth.[211] On one side there are grand decorations for scenes: thunderbolts, showers, snowstorms—these are made from cotton seeds, with bellows pumping. On the other side are Suns, stars, and the Moon on a fabricated heaven, which Nicolaus Siccus[212] (a man of the greatest distinction, and learned in every kind of knowledge and the nobler arts) represented in the comedy which he organized, produced, and designed at your request in the presence of Philip Prince of Spain and our Emperor's son. We saw the Sun and stars &910 glowing in a clear sky, hidden by black clouds, shrouded by white ones, a movement with a star and matched to the time the tale represented. There, people were fabricating sapphires,[213] chrysoliths,[214] genuine pyropuses,[215] lights hidden in glasswork, using dodecahedrons and icosahedrons with the natural colour of glass. The scenery emitted thunder, while you were looking at ships apparently sailing the sea and undulating.

The trouble taken here left nothing untried—including even nooses, hooks, nets, bows, dogs, hawks. And tricks are not enough unless traps are involved too.[216] There are three of them overall which catch all wild beasts or fish or birds: trick, force, and poison. Force is directed at birds with bow and arrows, at fish with a trident[217] and nets, also with lime shaken in a bag; it kills even those that taste nothing, or mentally deranges them, as baths can human beings.[218] And

[208] "argumentum."

[209] 1560 reads "Herba . . . imbuta pro coloris ratione alterutrum augentes chartae imprimitur . . ." and I surmise that "augente charta" was what Cardano intended.

[210] "ichnographia."

[211] A gum from plants of the genus *Astragalus*, importd from Persia.

[212] On Secchi, see Maclean, *De libris propriis*, 18 n. 34; he was made "Justitiae Praefectus" in 1546.

[213] On sapphire, see n. on "select sapphire" in Book IV at 316 (1560).

[214] See n. in Book VII at 435 (1560).

[215] A red precious stone (*OLD*). 1550 and 1554 mention here that there were no diamonds and emeralds, in case any suggestion of faking might arise.

[216] The details that follow are expanded after 1550.

[217] "fuscina." The transition of thought from the previous paragraph is hard to explain; hunting seems now the concern.

[218] "occidit enim nihil gustantes, aut mente deturbat, ut balnea homines." Sense unclear.

dogs and nets catch wild beasts. The poisons are aconite, spurge,[219] all the kinds of buttercup, which mixed with food kill all birds, beasts, and fish without discrimination. Nux vomica,[220] as I have found, immediately kills dogs; the same stuns birds, if mixed with their food. I remember that sometime I had mixed this seed ground up in flesh, and I picked up crows[221] by hand. If small birds eat grains that have been either in wine sediment with hemlock juice, or in strong liquor, or even just in the sediment of quite strong wine, or in a decoction of white hellebore with the bile of an old ox, they are stunned. Those that fly about in flocks are caught in flocks—for instance partridges, geese more than partridges, ducks most of all. &911 The tame ones from their own kind with wings clipped should be fed beside water and with a wall built round them, with plentiful and very attractive food there. For ducks, that means (among other things) uncooked sorghum in water.[222] While the tame ducks are quacking at night, the wild ones come down to the food; all animals show agreement in four calls: for food, for sexual attraction, for aggression, and for fear, and they understand each other. So when the nets (called "coverings")[223] are pulled in, the birds are entrapped and stick to the stakes and are enclosed— for instance, sometimes a thousand ducks are said to have been trapped in one effort. And though it may seem extraordinary, it is certain that no other kind of bird-catching is more successful. From the tame ones it is those that are closest to the wild ones in colour that are chosen.[224]

Fishes too are caught with food; the food should meet four conditions: to be odorous (since it attracts them from far away), like anise, juice of panaces,[225] and—better than all—cummin; to have a pleasing taste so as to attract and deceive the eaters, like blood (especially pig blood), cheese (especially goat cheese), bread (especially wheaten), and among these, butterflies; among them the tawny ones are better. It should be food striking the head, so as to carry the poison's power quickly to it, for instance alcohol,[226] wine sediment. Finally, it should be a poison which stuns them; of this kind is the "caltha" flower (called calendula),[227] which flowers in every month; this herb has yellow flowers, which if cut into slices stun even very large fish within an hour. There is a lime that kills fishes, even if it improves water.[228] And there is juice of any kind of spurge, and

[219] "tithymalum."
[220] Seed of an Asiatic tree, which contains the poison strychnine.
[221] Which had eaten it.
[222] "Sorgum incoctum aquae"; syntax unclear.
[223] "coopertoria."
[224] To lure the wild ones into the trap.
[225] *OLD* identifies this with several plants such as centaurea, lovage, and yarrow.
[226] "aqua ardens."
[227] Or marigold (*OLD*).
[228] The 1550 edition reported how the fish floated to the surface before Cardano's eyes.

both nux vomica and what is called "methel,"[229] or "the sleep-bringer." &912 But nothing is more notable than the fruit imported from the East called "cogolum"; it is a dark berry very like a laurel berry, but smaller and rounder. Our tested formula for catching fish is: a quarter of an ounce of oriental berries, a sixth of an ounce of each of cummin and alcohol, an ounce of cheese, three ounces of flour. These are compressed into pastilles and scattered. Mullein[230] kills fishes too. Pliny[231] recounts that the fishermen of Campania in his presence kicked birthwort[232] root into the sea with lime — the fish swam up to it and were killed. Crabs are taken with sticks divided at their top, into which some intestines or else frog bodies are put, and they are arranged near eddies or places which they normally inhabit, ten or twelve of them; then the fisherman goes round with a net, raising the sticks one by one, and putting his net underneath; the crab cannot disentangle himself quickly enough, and so falls into the net. So the fisherman is overjoyed to bring home one or two hundred crabs, sturdy and lively and large ones; the little ones do not approach the grand[233] food so easily, and when they have, they slip out before being captured.

There are not only things that attract, but things that repel, such as juice of gourd leaves, and if someone has soaked the hair of mules or horses in it in midsummer, they are free of the nuisance of flies, through a considerable miracle. The sediment of vinegar and black cummin[234] are also of use. But let us leave the enticements of the senses, and approach the more important part of the mind.

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229 This may be an Arabic word for something like garlic.

230 "verbascum."

231 Plin. *Nat. Hist.* 25. 54.

232 "aristolochia." The story is in Pliny: *Nat. Hist.* 25. 98; Loeb 7: 209; and in the present work appears first in 1560..

233 "sublimis."

234 "melantium."

[582] &913 Book XIV
On the Soul and the Intellect

Anyone who wishes to approach the powers of the soul,[1] especially the human soul, which is now our topic,[2] needs a new kind of discourse, because (as the Philosopher[3] rightly said), the soul is seen to be everything.[4] Things that can be sensed are so on account of the senses, and things that are understood are so on account of the intellect. I recall, however, that more has been said in the book entitled *De Immortalitate*,[5] as well as in other books we have written.[6] So in order to deal with the sense-bearing part of the soul, the beginning above must be repeated more profoundly; in fact sense-bearing knowledge is fourfold: the external, the conserver,[7] the combining,[8] the judgment;[9] the external is divided into the five senses; the conserver is a fourfold movement, and a state

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[1] "animus." "Âme" to the French translator of 1556.

[2] On the soul see also Book I at 15 (1560).

[3] Aristotle.

[4] Aristotle qualifies Cardano's quotation here "Now summing up what we have said about the soul, let us assert once more that in a sense the soul is all existing things" (Aristotle, *On the Soul*, 3. 8; 431b20–22; Loeb 3: 179; εἴπωμεν πάλιν ὅτι ἡ ψυχὴ τὰ ὄντα πώς ἐστι πάντα).

[5] *On Immortality.* Of this work of Cardano's, Maclean (*De libris propriis*, M2 [47]) writes that "Cardano's self-confessed obsession with posterity is well-known; this early work, provoked perhaps by the death of Niccolò Cardano in 1520–1, was destroyed before 1557, perhaps in 1538–9."

[6] 1550 and 1554, but not 1560, assert here that mind has two parts: a connected one divided into reason, memory, and imagination, and a separable one, comprising intellect and will. Also a sixth kind of "virtus," which knows what can be sensed. Then material present in all three editions is translated here in the next paragraph. Then material from [A] on 918 (1560) in the translation, "And appetite being twofold," nearly nine paragraphs further on, appears first in 1560.

[7] "conservatrix."

[8] "iunctio"; on this see the phrase somewhat further on, "combining between what is seen and the disposition to move the vocal muscles."

[9] "iudicium."

like that of a lyre-player, who strums with nothing whatever on his mind. Vision, or "phantasia,"[10] comprises things seen;[11] memory is of the other things sensed, especially of hearing. However, if its own power of conservation is allocated to each sense, and it is better and much more true for seven conserving faculties to be mentioned, as they should be—we call to mind odours and tastes, and the things we perceive by touch, yet there is no memory of such things. Furthermore, the closer each sense is to matter, the less we call to mind its sensed thing, as in the case of touch. But people decide on a common memory for four senses, because they differ little from each other, not in the way that the "phantasia" of colours differs from the memory of sounds, and also because things linked and comprehended[12] in memory seem to be retained as if that power was &914 common to them all. And so there are seen to be only four, and the last is named "mimnesis,"[13] which is the actual activity of recalling, and consists of manifold memory or vision, a process of thought. Combining[14] is not the power that recognises one thing after another; in that way vision too would combine, and memory that embraces the whole of an utterance at once—but not when several things are recognised as one, as shiny whiteness is on a wall along with its size—but when several things are adjoining as several things, or are in conflict, or compared, or when one is introduced from another. So there may be four kinds: combination, distinction, comparison, and consequence.[15] Judgment is comparison of several things grasped by reason, with their mutual relations,[16] from which a choice arises. The outcome is that people of strong judgment must excel in every kind of recognitions. Along with all the kinds mentioned, there are naturally six combined powers:[17] precision,[18] pleasure or pain, eagerness to pursue or flee, and this with a more convenient channel for assimilating and recognising what there is in common to be sensed; when the eye recognises a green wall, it also perceives its number, and its quiet, and size, and at the same time that the wall is not reddish nor white, in such a way that anyone believing this is otherwise is not deceived. But it does not distinguish—it is delighted by the spectacle of the wall too, and desires to see a dark purplish thing receding, without any

[10] The Greek word Φαντασία appears here.

[11] "Visio . . . est visorum."

[12] "intellecta."

[13] The Greek word μιμνήσις appears here, but μίμησις is the orthodox accentuation and spelling.

[14] "iunctio."

[15] "sequela."

[16] "cum suis conditionibus inter se."

[17] There are six combinations of three items, but the sense here is unclear.

[18] "ἀκρίβεια."

other reasoning activity occurring,[19] in the way that we see distinctly that an arm recoils from something pricking it, without any other thought—a phenomenon we also see in the &915 amputated tails of lizards when they are pricked—they recoil.[20] While the eye is seeing, it does not recognise that green is not white; like that, it would be comparing,[21] but while it is recognising green, it does not recognise white; in "what is, is this" it recognises that it is not something different, and likewise in connection with recognition it follows a straight path, though a shorter one, and this is the indication for stones while they proceed towards the centre of the earth.[22] We see people following suit as they yawn and sneeze;[23] apart from thought, we are stimulated to the same action, as we are to dancing and running and urination. All these powers and sensation-carrying recognitions receive completeness and incompleteness in various animals.

The only remaining problem is that of the common sense,[24] which does not seem essential—not because green is not sweet, because green is not white either; nor because green is different from sweet, because reckoning that[25] is to compare; nor because green is greener than sweet is sweet—each sense grasps this of itself; judgment belongs to reasoning. For size is twofold: one aspect is of expulsion,[26] the other of expansion,[27] and each is included under the common

[19] "Absque alia ratione, vel discursu"; I am indebted to Professor Maclean for pointing out that "discursus" means the "work of reason"; in Scaliger's words, "[Rationis] opera est id, quod discurrere vocant." And the *Lexicon philosophicum* of Goclenius identifies "discursus" as "mentis facultas, qua consequens et inconsequens, ordinem et confusionem iudicat." Hence the rather free translation here.

[20] "Oculus enim cùm viridem parietem cognoscit, percipit et numerum et quietem [This word appears here in both 1560 and *OO*. It is hard to understand. The whole adjacent passage is not present in 1550 or 1554. Perhaps "qualitatem" was intended—"quality"] et magnitudinem, et simul hunc non esse rubiginosum, neque album, ita ut non decipitur credens hoc esse aliud: non tamen distinguit, delectatur, et hoc aspectu et optat videre refugiens ferrugineum absque alia ratione, vel discursu, velut expressè videmus quod brachium refugit pungentem absque alia cogitatione, quod etiam videmus in caudis lacertarum praecisis, ac punctis, quae refugiunt." The syntax and meaning are obscure.

[21] "componeret."

[22] Stones find their route towards the Earth's centre, according to the Aristotelian theory of motion, by comparison; see further on the stone's movements at n. 37 below.

[23] "assimilatio"—following someone else's example. A reference to the observed fact that when one person yawns, others present will also yawn.

[24] "sensus communis." On Aristotle's use of this term, see P. Gregoric, *Aristotle and the Common Sense* (Oxford: Oxford University Press, 2007).

[25] "hoc rationis est."

[26] "extrusio."

[27] "intensio." Goclenius (*Lexicon philosophicum*) indicates that this word means a stepwise increase, especially of "qualities"; although he does not include "extrusio," its meaning is presumably opposite here.

sense. Thus beasts are endowed only with a simple and preserving recognition, even though they are very cunning, like the monkeys, elephants, dogs, foxes, swallows, parrots, and silkworms. So all animals are ignorant of comparison and of the significance of a substantive word, and lack judgment. The first generally accepted conclusion from this is that creatures that seem extremely cunning, judged by their techniques,[28] such as silkworms, bees, and ants, obviously lack these. &916 And so it is probable that swallows too build their nest in the same way as bees and silkworms. Further, though parrots and magpies learn to talk very well, but (even though they are extremely knowing animals) none of them was ever found who could fit words to things, though it could recognise and know its master and its master's name, since it is incapable of this: "This is the name of my master." But there is no reason to attribute such feats to them, since without them there is conformity with all experience.[29] The examples that can be produced on the opposite side are that dogs hunting wild beasts follow a straight route, and fawn on their master, and bark at anyone they do not know and at enemies. And that their mother appears to know the number of her sons, while recognising the loss of one removed during her absence. And while he pursues a hare obliquely, he does not make for the hare, but for the place which she [583] aims at. And he searches for his absent master in the places to which he used to turn aside. A sheep recognises its son, and a lamb its mother. And a donkey is afraid of a camel for being so big, but not of a sheep. Again, they are afraid of this fire and of a wolf, which they have not seen, but it looks like something else which has harmed them. And a fox dangles its tail in water and keeps it there till it feels it laden with crabs and minnows; it feigns death, to catch crows.[30] And an elephant making its way onto a ship demands an oath that it will return.[31] And when it has found a health-giving herb, it lifts it up to heaven, so that it appears to be giving thanks to the gods. &917 And lastly, one animal seems more cunning than another, so that it appears to possess cunning, and accordingly recognition that compares.

So it is well to know these animals, because they possess direct recognition alone; theirs generally surpasses what a human being has, for instance their vision and hearing and memory; and having so many good and surpassing direct recognitions, with the aid of those five powers even distinguished philosophers have regarded them as provided with cunning and recognition linked together, and with reasoning activity.[32] But they are not devoid of simple and direct vision,

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[28] "artificiis."

[29] "cùm absque illis omnia experimenta serventur."

[30] The traditional Aesop's Fable about the fox and the crow describes the fox not as catching the crow, but catching a piece of cheese which the crow had held in its bill.

[31] This story that elephants boarding a ship require an oath from their keeper that they will return appears in Pliny (*Nat. Hist.* 8. 1).

[32] "discursus"—see n. 19 above.

for instance, since dogs in their dreams howl because of what they have seen. Anyone who denies that there is the power of sensation in them does not deserve our refutation, but only to be put on a blind horse on a rough road, supposing himself made to press the legs of a rabid dog.[33] Thus first of all, it is a matter of experience that they fawn on their master because of the fourth power; because of the third, a mother recognises her loss; because of the sixth, she does not recognise number, which many human beings too fail to do; and nor does the eye, so as to be satisfied earlier.

Accordingly, number is a common sensed item,[34] and a muddled multitude, as properly defined, belongs to reason. The reason a dog gets ahead of a hare is as follows. Suppose a running hare is now moving from A to B, it makes for C, the dog is at D, from the fourth power it would make for B, a shorter route is to E, from the fifth power, so with a composite motion to C, and yet without reasoning activity.[35] For if it had such a reasoning activity, how would it work it out so unexpectedly, &918 that it would not occur to the mind even of a learned man after prolonged meditation?[36]

Then it should be said, on comparable reasoning, that while a stone is in motion, it moves sideways by violence, and towards the centre by nature, and thus on a middle line, because this would occur through recognition by the stone thus deliberating.[37] It [the dog] seeks its absent master, through a fantasy being presented, and finds him in the third kind of sentient recognition,[38] and with the help of memory; it recognises in this man its master, not that this man is its

[33] Reference obscure.

[34] "numerus est sensile commune."

[35] "discursus." See n. 19 above.

[36] Cardano's presentation of the problem is confusing, but may represent an aspect of the time-honoured puzzle that in a race, the quickest runner can in theory never overtake the slowest if the slowest starts in front of him, since the pursuer must first reach the point whence the pursued started, so that the slower must always hold an ever-diminishing lead. Aristotle (*Physics,* 6. 9, 239b15) expressed this puzzle, first posed by Zeno, in terms of a race between Achilles initially behind and a tortoise initially in front. It appears that some mathematicians are still wrestling uneasily with it; see for instance Dan Pedoe, *The Gentle Art of Mathematics* (London: English University Press, 1958), 140–41. Cardano's own account here of this paradox is barely comprehensible.

[37] "quòd hoc esset ob cognitionem lapidis ita deliberantis." In Book VII at 441 (1560) Cardano wrote, "We have shown previously that all things that are mixed are alive; this is especially appropriate for stones. They are not simply alive, but also undergo diseases, and old age, and later also death." But to write of them deliberating is a striking extension of his concept.

[38] The four kinds are listed at 914 (1560) near the beginning of this Book: combination, distinction, comparison, and consequence. The dog finds its master by comparing features.

master. The mother sheep and lamb recognise each other by smell and voice; we said that direct recognitions are actually the most outstanding among the operations of the mind, because the animals are not involved in composite things. From memory or natural disposition acquired from its ancestors (as happens with the swallow in nest-building), the donkey is stimulated to fear the camel from the third or sixth power, and the wolf from its disposition. It does not fear a fire through reasoning, but because is reckons it is the same as one that harmed it. About the fox and elephant: after it is granted by reasoning that no other animal possesses their sagacity, these examples (which can be observed in so many ways) mean that we do not need to be drawn into a suspicion that such animals possess a share of cleverness.[39] But as their senses are excellent, as I remarked, some of them seem cleverer than others, though not really being so—since they lack the positive, they must lack the comparative too.[40] So there are four parts of the human mind: combination,[41] judgment, understanding,[42] and will. [A] And appetite being twofold, the one without the power of sensation, and the other with it, sitting in the will and the sensory part of the soul are the affections themselves, such as pity, cruelty, wrath, clemency,[43] daring, fear, loyalty, treachery, modesty, shamelessness, hate and love, happiness, grief, desire, continence, sluggishness, alacrity, lasciviousness, self-control. &919 So the first subject will be the intellect and the will.

The "intellectus"[44] is the actual thing that is understood.[45] For instance, when I understand a horse, my intellect is the form of the horse, and accordingly

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[39] "sollertia."

[40] Evidently this means that if they lack cleverness entirely, they cannot be more clever than others.

[41] "iunctio."

[42] "intellectus."

[43] "mansuetudo."

[44] "intellectus," used in an unfamiliar sense here, which is not supported in classical Latin (*OLD*).

[45] "intelligitur." Scaliger joins issue here (*Exercitatio* 307(5) [930]): "Haec venena vtinam bibisses solus."—"I wish you alone had drunk this poison." And he proceeds in this 80-page critique, which dwarfs all the others, to a prolonged and detailed assault. Goclenius remarks that intellectus is "intricatum et plenum obscuritatis negotium," and I do not see support there for what Cardano says here. The French translator writes here: "L'intellect est la chose qui est entenduë, comme quand i entens vn cheual, mon intellect ist la forme du cheual."

is a general form, and (so to speak) primary matter.[46] But the will,[47] when being carried outside, is on that account posterior to the object, and is not the same as this object, but like it.[48]

So they differ in two features principally: the first, because the intellect is the actual understood thing, but the will is merely like it; the second, because the intellect is established at the same moment as the understood thing. And the will is subsequent[49] to it. As illumination and darkness are related to the eye, so are hate and love to the will, and false and true to the "intellectus."[50] But why does the truth follow[51] from both falsities and truths, but falsity never emerges from truths? The reason this occurs is that something of the truth can be contained in falsity, as "that he may be a donkey" is present in a man, because he feels. But in the truth, provided it is pure, nothing false can reside. So since a deduction from the whole to a part can be excellent, from falsehood truth can emerge, but never falsehood from truth. Yet truth never properly emerges from falsehood, but only from that part of the truth which resides in the falsehood.

So the intellect is influenced by understanding of the truth, with considerable joy, for three reasons: first, that this is the only task that is special in us, and shared with the gods alone.[52] Second, this function is of more important virtue; the task itself is the perfection of virtue. Third, because of the usefulness that follows the understanding and knowledge of truth. Falsehood is always hateful on its own account, but is welcome because at times it helps with the gratification of desire.

But we are charmed by aptly composed fables, because they look like the truth, and they include marvels, and therefore children are &920 more pleased by them than the elderly, and the stupid than the wise, because children and the

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46 As Scaliger remarks on this: "Intellectus Cardani est equi forma. Ergo Cardanus equus est." So Cardano is himself a horse! On notions of how the intellect worked, see E. Kessler, "The Intellective Soul," in *Cambridge History of Renaissance Philosophy*, ed. Schmitt and Skinner, 485–534; and Katharine Park and idem, "The Concept of Psychology," and G. Hatfield, "The Cognitive Faculties," in *Cambridge History of Seventeenth-Century Philosophy*, ed. Garber and Ayers, 2: 455–63, and 953–1002 respectively.

47 "voluntas."

48 The French translator writes here: "La volonté est, quand la chose entenduë s'offre exterieurement: et pource elle est posterieure à l'object, et n'est lors chose semblable à l'object, ains semblable à l'intellect." So he interpreted the meaning as "the will is not at that time something like the object, but like the 'intellectus'."

49 "posterior."

50 There is some slippage in the meaning of "intellectus," towards "what does the understanding"; compare n. 45 above.

51 "sequitur."

52 The French translator inserts here, "les autres choses nous sont communes auec quelques bestes, ou auec toutes, ou plusieurs," of which the original text occurs in 1550 and 1554, but not in 1560.

stupid suppose that there is more truth present in them. Further, what is heard is more pleasing than what is read; and among what is read, what is written in a foreign language is more welcome, and the scarcer books are, the more pleasure they give. The reason in all these is evidently rarity; rare material is present in rare books, known to not many people, being rarer than difficult books; what is heard is rarer, because fewer people know it, and rarest of all what is told to us alone.[53] So nothing delights a man more than treatises on matters both great and secret; what everyone knows grows cheap, even if worthwhile in itself. Hence priests wanted their [584]ceremonies passed down in secrecy, and there would be none of them except those sketched out in the gloom of obscurity. But obscurity is evidence of the ignorance[54] that does not put up with the understanding of writings, just as moderation is evidence of wisdom. It is the role of wisdom to put forward first of all the pretty doubts, and even if this can be done, then to bring up useful solutions and the cause, and to say nothing ludicrous about the presentation[55] of the cause. In this field, the greatest sinners are the Platonists.[56]

There are in fact three criteria[57] of[58] the intellect,[59] which it uses: principles,[60] experience,[61] and the consequences of these.[62] Since it gets from itself or from the senses what it knows at the outset, or it gets to know from these, it is evident that there cannot be more criteria used by the intellect; but others have other principles known to sense, or consequences. The mind has not laboured over these—it is in fact eternal, as is the species. Some of the eternal things do not

[53] Scaliger (*Exercitatio* 308 [997–99]) takes issue here and suggests that preference for heard material might arise through less work being required, through the attractiveness of the voice, through reading bringing on drowsiness, through embarrassment if one does not attend to the reader, etc.

[54] Reading "ignorantiae" with 1554 instead of the "ignorantia" of 1560.

[55] "Redditio"; but in this sense it is not classical Latin.

[56] The following paragraph appears first in 1554, except for the words, "contemplation itself stimulates the soul, and prolongs youth. We are actually alive only while we contemplate, since that is really the only life that is appropriate for the gods in eternity, and the only one in us is like that." which are also present in 1550.

[57] The Greek word κριτήρια is used here.

[58] i.e. "used by"; the French reads, "dont il use par iuger."

[59] The word used here is "intellectus" in the genitive case, so that the "understanding agent" is meant, not the "understood thing." There is persistent ambiguity in this passage.

[60] "principia."

[61] "experimentum." For discussion of the meaning of "experimentum" see Findlen, *Courting Nature*, 402–4, and C.B. Schmitt, "Experience and Experiment: A Comparison of Zabarella's View with Galileo's in *De Motu*," *Studies in the Renaissance* 16 (1959): 80–137.

[62] "consequentia."

change, such as God; some change in series, like the heavens; some in a cycle.[63] &921 Thus species are unmoving, yet not like that of the supreme intellect, but like the mind;[64] the mind does not labour, because it is not in time—rather, contemplation itself stimulates the soul, and prolongs youth. We are actually alive only while we contemplate, since that is really the only life that is appropriate for the gods in eternity, and the only one in us is like that.[65]

How words are carried across from writing into voice and further, to the intellect, may seem a trivial thing, because of its frequent use, and one of a single method, but it is a difficult one, and involves diverse methods. So before we speak of discourse, we must supply the things that we experience, either in ourselves or in animals themselves. What comes first is that when animals give forth a vocalisation by the power of sensation, as do horses when they see a female and whinny, they recognise an object through an external sense,[66] then through vision, which is itself the only—or the principal—internal recognising process.[67] They are then gratified,[68] and from gratification they are attracted, and impatient.[69] Then from the attraction they arouse not only a movement towards the thing seen, but also a display of joy,[70] and from the movement the vocalisation itself ensues. And so this transformation is performed through seven faculties or functions. Another point worthy of consideration is that beasts complete it without a combining;[71] this was shown previously, and nevertheless they cannot be trained by any technique to produce coherent vocalisations from what they have seen, but infants are trained before they can understand; so this natural conversion[72] &922 is granted to animals, and the conversion from things heard a second time into a contrived[73] vocalisation, as in the case of parrots, happens in infants through vision as well. Now if you exclude mind, the animals differ from the human being only in combining;[74] our discussion is now concerned with the will or judgment. It is worth enquiring why combining is needed—combining between what is seen and the disposition to move the vocal muscles; in the other muscles a similar rela-

63 "circuitus."

64 "ame" in the French translation.

65 The following seven paragraphs, to [B] on 925 (1560), appear first in 1560.

66 Hearing or scent.

67 "cognitio."

68 "delectantur."

69 "gestiunt."

70 "inde ex appetito motum, non solùm ad rem visam, sed etiam laetitiae indicem ciunt medio habitus, ex motu autem vox ipsa consequitur." I cannot fit the words "medio habitus" into the syntax.

71 "iunctio." Cardano is going to explain the meaning of the word in the next paragraph.

72 "transmutatio."

73 Reading "artificiosam" for the "artificiosa" of 1560.

74 "iunctio."

tionship[75] appears to exist in infants and in animals—although in fact animals are directed by natural appetite, but children by the fear acquired from memory; however, this does not make for any difference between them, since the relationship between pleasure and pain is the same in both, and it makes no difference whether they avoid the one or seek its contrary—though the fear does come with rather greater recognition than the natural appetitite; it is nearly to be regarded as natural, in view of the prolonged disposition.

Thus a total relationship of unlikeness exists in the combining between the seeing of words and the representation of sounds; since animals have not been trained to combine, even if in memory they could attach one word and also syllables to another word, but they cannot proceed from the imagination[76] of a seen thing into the imagination of a sound. Experience has told us this sufficiently, when children learn to read and produce a vocalisation of a sound from vision. Hence those who are deaf by nature are also inevitably dumb; though children do not perceive the sound of words, they do recognise the sound.

But you will say: "This seems to be a broader underlying distinction than you proposed earlier; what was assumed was that there is a distinction between the sight of speech and the pleasure, features that follow upon each other, as a third rank follows upon a second." But what now appears is a &923 consultation[77] between the sight and the sound of speech, indeed between the second and the final rank, so that the issue on which there is a return to the original problem, and the whole difficulty of the question, is still present. But both of these properly so—when indeed words are not understood by the little fellow, pain or pleasure cannot ensue any more than they do in animals too. So there is this primary distinction between the intelligent human beings and the beasts, but the second one is between infants and beasts, in relation to gaining knowledge by sight and by hearing.

There is then a further point of difficulty: why a combination should be made between things sensed by different senses, but it is not like that between things sensed by the same sense, and the more so because even animals appear to make the transfer from sense to sense; when they see milk from some distance, or perceive it by odour, they recall its sweetness and make their way to it to take advantage of it. And it is here that the greatest difficulty surely lies. But they do not do this because they know it is sweet, but they are (so to speak) making their way back to a white thing that previously gave them pleasure. They do not know this, nor can they represent it permanently.[78] It is for it to be said that this white thing is sweet, not for it to be achieved in imagination, but as we said above, all the knowledge that animals have too, whether external (such as is associated with

75 "ratio."

76 "phantasia."

77 "consilium."

78 "in aeternum formare possunt."

the five senses), or internal, is accompanied by attraction or avoidance, in relation to the feeling of pain or pleasure—from which follows the solution of the first and hardest question: when &924 things that can be sensed are of the same kind, for instance if a parrot reproduces a vocalisation it has heard, no knowledge nor representation is needed; disposition[79] is the principle of muscular movement.

We said that disposition is not the acquiring of knowledge; so what remains is that memory alone is essential for the production of vocalisations. So it must be reckoned that this acquisition of knowledge is a twin process,[80] and a human being can properly use both of them at once (after this has been granted to all human beings and to no animal; all human beings possess a mind, but no animal does) because of the presence of the double soul that is present in human beings—in fact the mind and the sense-bearing soul. [585]This makes clear to us that a human being from earliest infancy possesses a mind, because the human being can learn.

The way in which mind is made is easier to discern from written sources: from sensation there is vision; from vision there is combination; from a number of combinations there is general comprehension; from general comprehension there is a universal proposition; mind is made from a universal proposition, by the sort of combination that is called reason[81] and is fourth in rank when one conclusion is inferred from another. Hence there is no understanding[82] of simple things, nor mind made from them; but to understand in this way is divine.

In a topic which is very difficult for some people, but highly useful for everyone, I will make use of a very simple example. First, we see all the animals assembled, and that occurs while they are being branded,[83] and we recognise this. But the power that combines is the one noticing that this is the case; hence the animal senses by a proposition gathered from these three functions, and the general &925 comprehension is repeated by means of memory—even if this is an offensive thing to bring up in Latin, I shall bring up this and this on account of their obvious usefulness, as well as anything else of whatever kind that an animal senses, and from this[84] again a universal proposition is made, and every animal senses it. And so far this is not the special task of a mind but of a sense-bearing soul, so far as it is linked to a soul; then the animal senses a universal, and one special for a mind.[85] So from these too there are seven ranks of sense: the external imagining,[86] the combining, memory, general comprehension, universal

[79] "habitus."
[80] "duplicem hanc cognitionem."
[81] "ratio."
[82] "intellectus."
[83] "punguntur"; literally, "pricked."
[84] "ex qua," i.e. presumably from the general comprehension.
[85] Sense persistently unclear.
[86] "phantasia."

proposition, and the actual universal, which is special for the mind. And thus it appears that the faculty of the nourishing soul is linked to the general soul of everything, and uses its powers suitably; so from this proceeds the sense-bearing mind, and from it the mind of the sense-bearer again. The soul of the world is, so to speak, aided by everything. Thus these are the ranks of souls, of which the pinnacle is the intellect.

[B] Apart from acquaintance,[87] all the rest of the dispositions[88] alter the body itself, and with it also the condition of life, which will become clear from the following too:[89] all the senses are delighted and grieved by one thing or another. In response to delight itself, the spirits are carried outward, and retire within through grief, quickly in powerful dispositions, but slowly and gradually in small ones. It is evident that the blood too is conveyed along with the spirit. When it is carried outward, it is enlarged, cooled, and strengthened, if the powers are sturdy. When it is contracted, it is oppressed and consumed. If the heat is reinforced, a concoction will occur, sleep will be won, the excretions are digested, and &926 diseases are cured—as we will also explain below. But if the heat is reduced, sleep is prevented, concoction is impaired, the excretions are retained, and diseases are created.

So we need now to deal with a few dispositions of the soul,[90] so that we can approach others along the same lines. Thus in fear the blood is instantly gathered close together in the internal parts—hence people tremble, the voice is lost or falters, the body turns pale. And if this persists and is considerable, it brings on greyness of the hair, and in some people the hair falls out—sometimes even the nails—and with the blood gathering inside, the person either wastes away, or with the stirring up of a phlegmon he stands in mortal danger—some people have been suddenly snuffed out.

But in grief the heat does not return *en masse*, but little by little; and so the legs do not falter, and people[91] do not die suddenly, but stay awake; the vital parts[92] are not concocted; young men suffocate; those of advanced age waste away from disordered juices;[93] there is a bad colour, and diverse diseases hold people in thrall. It is on account either of this or of fear that the tale runs about

[87] "notitia" (acquaintance) in 1560, but 1554 reads "laetitia."

[88] "affectus."

[89] Reading with 1554 "Immutant verò et praeter laetitiam affectus omnes reliqui corpus ipsum, et cum eo etiam vitae statum, quod ex his erit manifestum." 1560 reads "immutatur" and "notitiam" and "vita statum."

[90] "animus."

[91] The legs, according to the syntax, not the people.

[92] "Praecordia," sometimes means the costal cartilages, as in Fernel's *Physiologia* (I chap. 7, ed. Forrester and Henry, 66), but for classical and less specific meanings, see Onians, *The Origins of European Thought*, 40–42.

[93] "cacochymia."

Meliboea daughter of Amphion and Niobe: when of so many brothers and sisters, one sister and she alone had made their escape, she became pale for good.[94] So she was called Chloris[95] afterwards. Wrath suddenly pours out heat externally, but beforehand it is so warm that in hotter and drier temperaments a fever is evoked. In all of these, the whole body certainly warms up, so that wrath is of use to those in whom phlegm or grief is abundant, or the bodily structure is shrivelling up from fear.

Powerful happiness conveys pure blood outward, so that it regularly cures diseases in those of strong powers, but &927 is lethal in weaker people, and is a remedy for wrath, but more so for fear. But hopefulness is the contrary of grief,[96] and if it is free of fear, it distributes the natural heat gradually.[97] Hence of all the conditions of the soul,[98] hopefulness alone is of use to everyone; it produces concoction and sweet dreams, thus also rendering the body well coloured, and fatty without limit. However,[99] hopefulness is closely similar to rejoicing, and does not permit sleep; any strong movement of the blood abolishes sleep, since sleep is the repose of the spirits and blood.[100] Modesty arises from hopefulness, and from fear, and accordingly in it the blood ebbs and flows in a double motion, one familiar in boys and girls, and it flushes the face with attractive vigour, and is not distressed, as during fear it contributes not harm but rather resentment.

Resentment is itself the product of hopefulness,[101] but also from sadness, not from fear. Envy is a slender sort of resentment. So it is clear which conditions of the body spring from resentment and envy. But since love is the contrary of resentment, joy will be regarded with mistrust; mistrust is the contrary of hopefulness—I mean of steady hopefulness, just as fear is the contrary of variable

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[94] This tale is told by Pausanias (2. 21. 9) and others, the versions not being concordant in any detail. Essentially, Niobe the mother boasted presumptuously of the number of her children, and those children were then slaughtered by Apollo and Artemis, but two escaped: Meliboea, who turned pale for the rest of her life and so was subsequently called "Chloris" (the pale green one), and her brother (not sister) Amyclas. Cardano introduces this reference first in 1554. See n. in Book XIII at 875 (1560).

[95] Derived from the Greek χλωρός, meaning "pale."

[96] Not so, argues Scaliger (*Exercitatio* 314(1) [1009]); fear is the contrary of hopefulness: the one the expectation of good, the other that of ill.

[97] Reading "sensimque si sine timore sit . . ." with 1550 and 1554, not the "sensimus, si sine timore sit" of 1560.

[98] "animus."

[99] The French translator inserts "immoderée" here, but it is not in the Latin.

[100] Scaliger (*Exercitatio* 314(2) [1009]) denies this; neither is ever completely at rest. And in consequence, bears, dormice, and marmots fatten mostly during their sleep. And monks are no worse at doing this!

[101] Reading "ex spe compositum" with 1550 and 1554, not the "ex spe compositi sunt" of 1560.

hopefulness.[102] Mistrust is a little fear, just as boldness is the utmost hopefulness. It differs from joy, since in both there is steady hopefulness, but in boldness the outcome is intermediate—in joy it is happy. It is a good plan to recall this later, so that what turns up can be understood, but it all alters the body so much that if combined with melancholic humour, they induce a trance:[103] if you burn them,[104] or cut them with a razor, you will find they feel nothing. Others willingly lie down &928 as if dead, others too practise divination, and among the inexperienced these things are reckoned major miracles, though Hippocrates says, "If the tongue suddenly becomes unrestrained, or some part of the body droops in numbness, this sort of thing is melancholic."[105] But Galen did not grasp the meaning of this, and so is astonished at the words of the old master.[106]

So conditions of the soul[107] alter bodies, and sounds alter the conditions of the soul. Hence sounds must alter bodies. The greatest of all conditions are fear and courage, and [586] sounds can stimulate these—trumpets demonstrate this, the Spartan invention of drums, the horns of the barbarians, and the shouting of the Romans—at the start of a battle, the Romans used to make such a huge din that Josephus was forced to block the ears of his Jewish soldiers, to stop them being terrified or getting stunned.[108] It often happens that birds passing over drop down because of that din.

So it is agreed that sounds contribute much to courage, and then to other conditions of the soul.[109] Now shouting is replaced by the roaring of fiery machines with a serious and deadly sound. How much bodies are influenced by conditions of the soul[110] is shown by those who neither see nor hear while concentrating attentively:[111] their eyes are open, or their ears, but they cannot see nor hear. But they can concentrate, and consequently feel less, so that at times when concentrating they do not even feel pain. [C] The body must be affected by conditions of the soul,[112] since these people do not become bodiless. But their intellect is not

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102 Presumably the meaning is that mistrust is a lasting condition, the contrary of permanent hopefulness, while fear can be transient, the contrary of transient hopefulness.

103 "ecstasis." 1550 and 1554 include "stupor" ("numbness").

104 I.e. the victims.

105 Hippocrates, *Aphorisms*, 7. 40.

106 The next eight sentences, to [C] on 928 (1560), appear first in 1554.

107 "animus."

108 Josephus was the Jewish leader besieged in Jotapata, a village in Judaea under ferocious onslaught by the Roman army in A.D. 67. He also composed an account of the whole war (Josephus, *History of the Jewish War*). "He [Josephus] instructed his men, when the legions raised their war-cry, to stop their ears, so as not to be frightened" (*Jewish War*, 3. 259; Loeb 2: 651).

109 "animus."

110 "animus."

111 "dum cogitant intentius."

112 "animus."

altered, except &929 in case it needs to function with reasoning and imagination, or in case the whole person takes pleasure in comprehension; the intellect itself is of itself entirely separated from the body.

While I am actually writing this, my intellect is the things you grasp through what I have written: medicine while I discuss medical matters; arithmetic at the time that I was writing about numbers, so much so that as must happen to everyone else who has been an author of various works, while I read over what I have written, I think myself different from the person I now am. But in mid-activity,[113] a person does not grasp or perceive the starting points.[114] Thus while a person is asleep or is still an infant, or is drunk, though he seems to be unoccupied, he understands, but the process is not shared by its owner;[115] when he recovers his senses he understands once more, without difficulty.[116]

The evidence is that we do see, yet do not perceive ourselves seeing, unless we pay attention. A sense is at rest in the absence of an object; it is simply passive, but the soul is active, and when it wishes, it understands at once—so why does it stop? Again, the senses perceive at once, but the soul is more divine, so that it has no need of time, and perceives more reliably. It therefore is devoid of matter; warming up and cooling down, and permeating with odours, are events that occur gradually.

While we are understanding something, do we always notice we are doing so? Is this essential, or may it perhaps be impossible? — except when we perceive what we understand?—an almost divine process? At the time the intellect and what is being understood are in fact the same; for the rest of the time, we perceive that we have understood, and are going to understand, since only one action can be accommodated. The form of the &930 intellect is therefore eternal, since while you are reading and contemplating this, it abides and exists, and the forms and the species of universal things are evidently the same forever. So the souls[117] especially of wise men are immortal, and the "anima" a flame—the "anima" cannot persist without it, nor without movement.[118]

In a sensation, there is no alteration, and accordingly it passes away, and even what we are sensing does not stay the same. Hence we do not carry out imagining or the use of our reason in the same way. Memory, so to speak, is more like the intellect. It is aided by its sequence[119] since what exists in sequence is so readily

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113 "medio tempore."

114 "principia." 1550 and 1554 include in this sentence, "just as he does not notice himself performing sensation, since his mind is abstracted."

115 "sed non fit operatio habenti communis."

116 The following seven sentences appear first in 1560.

117 "animi."

118 "anima verò flamma quaedam, aut non sine illa, neque enim absque motu consistere potest." Syntax obscure.

119 "Ea ordine iuvatur."

kept together that it looks like a unity. There is a double sequence, of things and of words: the one protects the other, so as also to be double; contrived[120] memory, consisting in images of things, was long ago discovered and handed down by Cicero and Quintilian, by which[121] the words are held together; and memory of words, by which the things and the words too are held together; it consists in the opening syllables of words, or even of the starts of words, from which words and charms too are made.

Of the same sort is the memory that consists in a combination of numbers; it is extraordinary how much each method contributes to extemporaneous actions and games. Hence we have reaped the reward of our so pretty invention, that is, the view of memory that has helped us most, although the whole thing is attributable to a stone and to this discovery,[122] whatever the whole thing is, beyond passive memory, which thrives in us. Active memory, and especially both sorts of contrived memory, is especially assisted by imagination. And contrived memory is practically nothing but the transfer of things and words, &931 according to rank and to the power that imagines; yet it offers so much advantage (contrived memory of words and numbers) that you can repeat a hundred of them with its help more easily than ten without. The ability to reason is of all human virtues the main one, and special for the human being, as he is mortal. But as he possesses an intellect, he cultivates the arts and sciences, and some technical inventions that are not related to the arts, since they lack usefulness, or are of uncertain kind; every art is of a definite and useful kind. To indefinite and useless things we must now turn.

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[120] "artificiosa." On artificial memory systems, see P. Rossi, *Logic and the Art of Memory* (London: Athlone Press, 2000), and F. Yates, *The Art of Memory* (London: Routledge & Kegan Paul, 1966).

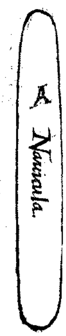
[121] Reading "qua" with 1550 and 1554, not the "quia" of 1560.

[122] "cùm tamen lapidi atque huic inuento debeatur totum quicquid est, praeter passiuam memoriam, quae in nobis viget." Text identical in 1550 and 1560. I have not made sense of this "stone."

[587] &931 Book XV
On Useless Subtleties

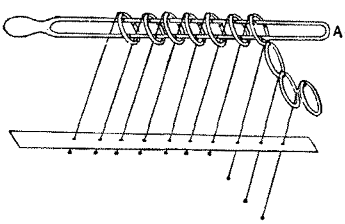
Points of this kind are the following: when a blow falls on one panel, why is the panel below not much shattered, as occurs in the driving in of wedges? Surely this is because the blow is distributed throughout the whole of the panel below, so that less of it breaks up into individual parts, and no part is compelled to move down and leave another behind — the major starting-point of fracture. And with it[1] in the middle, the blow is modified. Air too, if it is without an impulse, cannot make a violent entry in the direction of the second panel, and therefore cannot split it either.

A similar question is: why do glass vessels exposed to fire with a twig on top not break? Because the wood does not heat up, and make the parts of the glass mix together; &932 but it does break up, because the watery moistness is converted previously into flatus. And a tool made from seven rings is of no use. A thin layer of iron a finger wide, a palm[2] long, thin and with seven rounded apertures in it, narrow, and arranged at equal intervals lengthwise, receives seven thin rods nearly an inch high, movable at the bottom, and at the top bent round so as to hold closed rings a finger in size; the rods themselves are held by the sub-



sequent ring below the bend. Consequently all the rings (apart from the first one) are stopped by the preceding ring from jumping freely outside the front rod. It is all of iron, and there is a small iron boat (we presented an accurate picture in the margin) that is long and wide according to the size of the underlying layer. With this tool a game of marvellous subtlety has been devised. The first and second ring is inserted through the empty space A, and then the little boat through the same rings. Afterwards, the first of these is passed through the empty space A, after which the third ring is drawn upward through the empty middle part of the boat, like the first two, and is pushed into the boat. Then when the first is drawn upward, there are already three moving round the boat; you will pull

[1] The starting point; the word is neuter, while the word for "panel" is feminine.
[2] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.



out the first two after taking out the boat first; so only the boat will remain shut in the third one; next you can pull a fourth one over, so that all this hard work is covered by three instructions. First, that the ring to be pulled up and let down should have only one in front of it, in which the boat is to be enclosed. Second, while you are letting down, you should always let down the first two together, and pull one up, or &933 while letting one down pull up the first two. Thirdly, whichever is pulled up or let down, all those in front must be pulled up, and again be let down. And so the first two are not blocked by any other; the one I call the first ring is the one that is free in sixty-four exchanges.[3] If the operation is free of error, the boat is enclosed in all the rings, and encloses all the rods in thirty-one others, so[4] that there are ninety-five from the finish to the passage of the first or the last, and the same number returns. So the circle will be completed in a hundred and ninety exchanges. This is of no use in itself, yet it can be carried over to the bars made for chests.[5]

There is a similar subtlety in the game of robbers, but more pleasing because of its variety and competition; just as the little boat is a very subtle invention of its kind, so are the robbers among all the games. We have written four books in the past about *Games*.[6]

Of[7] the same kind is the method of getting to know a piece of paper that has been worked on. Make someone conceive it in his mind, then show it to him detail by detail; when he has nodded, you will mark the paper secretly with your finger, and at once mix it up, then show the paper you have found. Other people place it before a mark, and mix it, and before it is separated, they look, then separate it, or on the decision of an associate they leave it. Others hunt by frequent division of numbers. Of no use too is the subtle trick[8] which teaches that all com-

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[3] "vices."

[4] The wording of the passage here is slightly revised in 1554.

[5] Perhaps as a sort of lock. The arrangement of the "Chinese puzzle" here described and the deductions about the number of moves required are very difficult to follow here, but are set out in detail by W. Rouse Ball, *Mathematical Recreations*, 11th ed. (London: Macmillan, 1940), 305–9, where the figure provided here below Cardano's own appears. He states that the puzzle is "on sale in most English toy-shops," and that Cardano "attacked its solution unsuccessfully"; he offers a solution of the problem of the number of steps required to remove any specified number of rings. The puzzle is nowadays rated "very difficult," and is also marketed under the name "Patience Puzzle."

[6] The four books *De Ludis* were written in 1523–1524. For further details, see Maclean, *De Libris Propriis*, M3 (47–48).

[7] This and the two subsequent paragraphs appear first in 1554.

[8] "subtilitas."

mercial dealings can be split by the price of a quarter,[9] even if the value is &934 a thousand thousand. Suppose there is a horse, for instance, worth a thousand thousand, which you are going to sell to me for that sum; I wish to show that the sale can be split by a quarter.

For if I am to offer five hundred thousand, and you reject this, I shall offer nine hundred thousand, and if you do not accept, I offer nine hundred and fifty thousand; if you refuse this, again I offer nine hundred and eighty thousand. If you accept this, I offer nine hundred and seventy thousand. If you do not accept this, I offer nine hundred and seventy-five thousand. If you do not accept this, you will receive, for example, nine hundred and seventy-eight thousand. I ask whether you will accept a thousand less? Then five hundred? In the end, get to a hundred, and fifty, then to ten, then to separate pennies, then halfpennies, then farthings—in the end you will get to obols, till the sale gets to being split by one obol. You will show this more clearly if you put the question with rises of single obols; it will be compelled to fall into one of two ridiculous coins, so that he may actually sell on the addition of an obol what he would not sell previously before the obol was added, or refused to sell at any price.

And so our shrewd invention, with its [588]outstanding subtlety, is of no use, except to entangle and weary the respondent in a sophistic question. But in every food there is refuse, and where there is refuse, there is always food.

A third kind of useless subtlety may be seen in the books of Raymond Lull.[10] Something laughable: to want to pass on a &935 complete doctrine without knowing any! But[11] as we have quite carefully remarked, the discovery has been seen as not to be wholly despised; it is in fact possible to convey the whole of an art such as Medicine on twelve sheets of paper at most. For instance, we have covered not just Medicine, all of surgery, and pharmacy, with the signs and natural principles, as well as examples, in twenty-six sheets on this basis, with the addition of authorities and demonstrations, where I felt that they were required. So this book will appear. But now it is well to expound a method taken from

9 I.e. a coin of small value.

10 Raymond Lull or Llull (ca. 1230–1315) was a philosopher born in Majorca who wrote works in Latin, Arabic, and Catalan, especially his unique logical dialectical system repeatedly modified, his *Art*, which supported Christian doctrine against that of Averroes, and was "one of the Middle Age's most ambitious and enthusiastic projects for exhorting the soul to righteousness" (M. D. Johnston, *The Spiritual Logic of Ramon Llull* [Oxford: Clarendon Press, 1987], 319). J. N. Hillgarth, *Ramon Lull and Lullism in Fourteenth-Century France* (Oxford: Clarendon Press, 1971) provides a detailed biography, critique of the works, and account of their role in subsequent thought.

11 Material from here appears first in 1560, an edition in which some three Latin sentences on the subtlety of Plautus in the earlier editions here are not translated. Material onward from [X] on 936 (1560) first appears in 1554, and from [Y] on 937 (1560) in 1550.

the secrets of Arithmetic. Any art which comprises things, not opinions, can be contained in twenty simple rules;[12] when twenty end-points are set out, the combinations established are 1048375.[13] The most complete basis for this number is as follows: unity[14] 20. For 19, the same.[15] For 18 and 2, multiply 40 by 19, which gives 760; divide by 2, 380 comes out. For 17 and 3, multiply 18 by 380, and divide by 3; 2280 comes out. For 16 and 4, multiply 2280 by 17 and divide by 4; 9690 comes out. For 15 and 5, multiply 9690 by 16 and divide by 5, and thus always multiplying the aggregate, passing through the greater preceding number and dividing the product by the lesser number, you will come in sequence to 10 which is in the middle; since it lacks an equal,[16] multiply the preceding aggregate, which is 335920,[17] by 11, on a general basis it becomes 3695120. Divide by 10, it becomes 369512. But because this number is made up of likes, we will accept only the mean, which is 184756. When all &936 are gathered, and unity added for the sake of the rule, which is made from all the simples, there will be as I said all the rules, 1048575 [*sic*]. Since all the books of the [mathematical] art—Greek ones, Arabic ones, and Latin ones—do not contain even the twentieth part, it is agreed that the simplest rules are either not of the same number, or all the combinations are not fulfilled. So since twenty rules as well as the methods of combination can be held on two pieces of paper, the whole art will be held. Thus three books on *Difficulty of Breathing* are held in two rules (since Galen

[12] "regulae."

[13] *sic*; this number appears later as 1048575, and both are incorrect, the correct number being 1048576. For explanation see n. 15 below.

[14] "singulares."

[15] I am indebted to Professor Alex Craik for pointing out that Cardano appears to be reckoning the number of different ways in which twenty different objects can be assigned to two different baskets, although it is difficult to reconcile this precisely with Cardano's words. The ways are in present-day language the *binomial coefficients* for n=20 and r= 0, 1, 2, 3 . . . 10. Start by placing all 20 objects in the first basket and none in the second, which can be done in one way, and similarly there is one way of putting all 20 in the second basket and none in the first, making in all two ways. Then there are 20 ways of putting 19 in the first basket and one in the second; and 20 more of putting one in the second and 19 in the first. There are 190 ways of putting 18 in the first basket and 2 in the second; and 190 more of putting 2 in the first and 18 in the second, making 380 in all, as Cardano reckons. And so on. Finally, there are 184,756 ways of putting 10 in each basket, which number "lacks an equal," i.e. is not to be doubled, since there is an equal number in each basket. The grand total of ways is 1,048,576.

[16] N.B. if you follow the sequence down to the 20th term, it rises to a maximum at the 11th term, which thus "has no equal." Each term comprises the previous term multiplied by (22-x)/(x-1).

[17] 1560 reads 325920, which is incorrect.

omitted a third).[18] What depends on human opinion is excepted: Jurisprudence, Grammar, Geography, Theology, Rhetoric, Poetry, History, for these are within a number of simple rules.[19]

[X] Putting books together is part of the same argument, that is, of trouble uselessly wasted—if you deny that in them something of the whole basis of argument cannot show, everything would completely collapse. Consider for instance someone who is searching out the origin and principles of natural things from the oracles of the Sibyl[20] and the ambiguous and fabulous authorities of the poets, and strives to show what they are—they appear to teach a most beguiling[21] occupation for mortals: I mean, to pass time. And so it is right for this kind of writing to be condemned, decried, rejected by Galen in his books on the *Decisions of Hippocrates and Plato.*[22] What could be more absurd, indeed foolish, than to look for testimony on serious subjects and those requiring the most reliable proof, from oracles and poets, whose mind was turning on nothing less &937 than what they would write down?—and they were only aiming to complete the line of verse[23] and let the poem sound out. To the same class belong the Theologians debating in natural arguments against the Philosophers, and the discoverers of all heresies,[24] and those who talk about making seals under specific states of the heavens, and those who deal with natural magic derived from a numerical

[18] Galen wrote a three-book work on difficulty in breathing (*De Difficultate Respirationis*; K. 7: 753–960). It is not clear what is meant by "Galen omitted a third." The whole argument is obscure; a little earlier in this Book, Cardano wrote that any art could be contained in 20 rules—except those that depend on opinion. Here, he seems to overlook this exception, and mentions a complex issue (difficulty in breathing) which can apparently be covered in two rules!

[19] "regulae."

[20] The Sibyl (or Sibyls: they were often plural) were prophetic females located at various places during classical antiquity, notably near Cumae south of Rome in Vergil's *Aeneid* (Book 6), and various collections of their prophecies were compiled; for further details see *OCD*, and there is further information in n. to Book II at 210 (1560).

[21] "charissimam"—Latin transcription from the Greek word.

[22] It is difficult in this Galenic work to identify any particular passage that Cardano had in mind, but possibly the following: "Sometimes he [Chrysippus (c. 280–207 B.C.), a very prominent Stoic philosopher] calls on poets, or etymology, that fine friend, or something else of the sort, things that prove nothing but spend and waste our time to no purpose, as we make this one point clear to them, that the premisses of the syllogism are not scientific, and then descend into the arena and wrestle with them in order to demonstrate that the non-experts and poets testify for us no less, and sometimes even more, than for them" (Galen, *On the Doctrines of Hippocrates and Plato*, 2. 2. 5, trans. de Lacy, 105).

[23] "numerus."

[24] Or "schools of thought."

basis, like Agrippa the unlucky;[25] as Aristotle[26] correctly said, the numbers of actions and changes cannot be principles.

In fact, what is written down should have three characteristics: immediate utility, a definite end, an impregnable foundation. [Y] Hence the subtlety of Rabanus should be reckoned among the useless items—a work of huge labour and quite painstaking.[27] He preserves the arrangement of a poem and metre first, then he explains the image of pictures instead of letters, by lettering included in the figure; then he assembles the meaning[28] and story of the figures, and with these too he builds up his poems. He explains afresh the whole meaning of the included figure by a complete series of poems.[29] Thus by his art he depicts crosses, trees, birds, and other things without number, and the following is one example.

&938 "O tree strong in fragrance, widespread with leafy top, from which in spring the highest richness flows in a sacred order, enriched garden no peer of which in flowers and leaves exists in the world. Rich in thousandfold fruit, surpassing all high forests in majesty, when great honor and glory piously clothes all of you, true honor surrounds you. The happy man standing there says these

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[25] "Agrippa infelix"; this is Heinrich Cornelius Agrippa von Nettesheim (1486–probably 1535) who was a German philosopher, theologian, diplomat, and historian, and wrote extensively on the occult, while pursuing a wide range of occupations in France and Germany, unlucky in being persecuted and harassed. M. Van der Poel (*Cornelius Agrippa: The Humanist Theologian and his Declarations* [Leiden: Brill, 1997]) includes a concise biography and reference to others.

An "enigmatic humanist and magician" (Keefer), Agrippa belongs to a loose grouping of philosophers usually referred to as "Renaissance Neoplatonists," and was reputed a magician. On his natural magic, see G. Molland ("Cornelius Agrippa's Mathematical Magic," in *Mathematics from Manuscript to Print*, ed. C. Hay [Oxford: Clarendon Press, 1988], 209–19) who explains that for him geometry and continuous quantities were of little significance in nature; for Agrippa and many predecessors the whole numbers (collections of units) were what mattered in nature, e.g for the number of the planets. Kepler later reversed this view. Agrippa also wrote *On the Uncertainty and Vanity of the Sciences* (1530). On his role in the world of magic and religion of his time, see P. Zambelli, "Magic and Radical Reformation in Agrippa of Nettesheim," *Journal of the Warburg and Courtauld Institutes* 39 (1976): 69–103; and M. H. Keefer, "Agrippa's Dilemma," *Renaissance Quarterly* 41 (1988): 614–53; Cardano thought little of him: "utterly mercurial . . . his book devoid of factual information . . . ignorant." (In Cardano's *Liber de exemplis centum geniturarum*, at *OO* 5: 491, cited by Fierz, *Cardano*, at xx–xxi.)

[26] Reference not traced.

[27] Rabanus Maurus wrote his encyclopaedic *De rerum naturis* (or *De universo*) between 842 and 846. Text available at http://www.mun.ca/rabanus/. Accessed on 23 Feb. 2008. See M. Frassetto, "Hrabanus Maurus," *Oxford Dictionary of the Middle Ages* 2: 816.

[28] "sensum."

[29] See *Rabani Mauri In honorem Sanctae Crucis*, ed. Michel Perrin (Turnhout: Brepols, 1997).

Arbor odore potens, f r o ndoso vertice nata,
Qua summa verè sacr o, u f luit ordine bertas,
Hortus ditatus, & pa r c u i nullus in orbe est,
Floribus, & foliis, m i l leno germine dives,
Omnes excedens alt a s g ravitudine sylvas,
Cùm totam piè magnu s v e stit h onosque, decusque,
Ambit verus h onor, l a e t us loq uitur ea voto,
Stans homo li vor ho c n a tioni denegat atrae.
Dæmonis horrendus r e m sciri laude moveri,
Arbor sola tenens v a r i os virtute colores:
Purpureo regis sub t a c tu roscida fulgens,
Aeterno es radio, st a n t in te nam piè vincta,
Aedes turritae, ex ho c d u dum es nomine beata.

things in prayer. The dreadful anger of the black demon forbids the people to know this or to be moved to praise. O only tree having various colors by nature, shining with dew touched by royal purple, you exist in eternal brightness, for in you stand the towered buildings piously linked together, and from this surely came . . ."[30]

&939 [589] If you notice, this poem is read by moving downward: "The sacred form of the cross glitters with august drapery." And again, while you proceed from right to left, this other item in the enclosure: "great honour clothes me, I am happy to say this to the nation."[31] Plautus[32] used a similar artifice, in writing

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[30] "laetus loquitur ea voto, stans homo livor hoc nationi denegat atrae." While the sense and syntax are obscure, note that in the cruciform enclosure in the page reproduced above, it is possible to read horizontally "magnus vestit honor, laetus loquor hoc nationi." And vertically: "forma sacrata crucis venerando fulget amictu": "The sacred form of the cross glitters with august drapery." Cardano has reproduced rather less than the top half of the original Figure, which can be found, as Ian Maclean has shown ("Montaigne, Cardano," 154, n.12), in Rabanus Maurus, *De Laudibus Sanctae Crucis*, lib. 1, Fig. 13 (PL 107. 199). His version differs from Migne's at six points. They are (Patrologia Latina first): lata/nata, Ortus/Hortus, honorque/honósque, atri/atrae, vincte/vincta, est nonne beata/es nomine berta. Cardano's seems the better reading each time. See *Raban Maur: Louanges de la Sainte Croix*, trans. Michel Perrin (Paris: Berg, 1988), 72–73, 198–99.

[31] "Great distinction clothes me, I am happy to address that nation."

[32] 1550 and 1554 include here three sentences not found in 1560: "Quae se coniunctam in se haberent aliquam . . . homines usus est." Otherwise after this point the

the name of the argument of a play by the leading letters of the words that stand at the start of the argument of the play.[33] But that was more appropriate for a Comedy playwright than if he had started this scheme by pre-arrangement, devoting himself wholly to it. For instance, Hubaldus Gallus,[34] an Eluomensian monk of the order of St Benedict, who wrote the praises of Charles the Bald, King of France[35] in a hundred and thirty-six poems, of which the individual words had the letter C as their start, and their opening is: "Sing, O Poetry, clear-sounding songs to the bald."[36] Similar is the work of Placentius Porcius, who sang of the battle of the pigs in about three hundred lines, of which the individual words start with the letter P.[37] There remains with me a not unprepossessing work which opens: "Clap, piglets, idle offspring of pigs."[38]

But if this had any usefulness linked to it, I would think the man worthy of the highest praise; however, now we can mock his effort as much as we admire his talent. A quotation can give pleasure—a quantity of them surely leads to boredom. And this is almost the one feature common to items that are useless for humanity.

&940 These almost resemble the energy of that distinguished man who would strike any place he wished with a chickpea,[39] and earned a measure[40] of chickpeas from Alexander; Alexander was more disgusted by the pointless labour than impressed by his industry.[41] [Y] A similar, but somewhat more useful, case is the four *Geometrical Books* of Proclus[42] on the *Elements* of Euclid; they

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material to Y on p. 940 first appears in 1560.

33 Plautus outlines the story of his plays at their start in the "Argumentum" and its lines open with the letters of the play's title, e.g. that of his play *Amphitruo* starts, "Amore captus Alcumena Iuppiter / Mutavit sese in formam eius coniugis / Pro patria Amphitruo dum decernit cum hostibus. / Habitu Mercurius . . ." etc.

34 Hucbald (Hucbaldus, Hubaldus; born about 840 A.D. at Tournai in France, died there in 930) was a composer, teacher, and writer of the "first systematic work on western music theory." See C.J. McDonough, "Hucbald of St-Amand," *Oxford Dictionary of the Middle Ages* 2: 817.

35 Charles I, King of France (843–877) and (as Charles II) Holy Roman Emperor from 875–877.

36 "Carmina clarisona caluis cantate camoena."

37 This sixteenth-century poet wrote a poem, "Pugna porcorum," of 253 hexameter lines, in which every word began with the letter P.

38 "Plaudite porcelli, porcorum pigra propago."

39 "cicer."

40 "modius"—approximately 9 litres in volume.

41 I have not been able to trace this allusion.

42 Proclus was a Neoplatonist philosopher (A.D. 410–485 approximately), and wrote a commentary on Book I (only) of Euclid's *Elements*. It added but little ("Proclus n'apporte guère de son propre fonds que des reciproques et des demonstrations de ces particuliers non traités par Euclide, et qu'il emprunte de nombreuses variantes de demonstrations aux

do not actually teach anything new, so that they have little relevance to the art. However, since subtlety is diverse, and not all of a kind, as in Rabanus and Lull,[43] they should not be entirely discarded and despised as of no use; as there are many instances of subtlety, the art will also be one.

It was thus with an aim similar to that of Proclus, but with more of a youthful boastfulness than obvious usefulness, that I and Ludovico Ferrario[44] discovered in a few days the way in which everything proved by Euclid could be perfectly shown by us, by altering the breadth of the compasses (at whatever breadth), away from the opposing and invariable proposed breadth—except for the inscription and circumscription of circles. Although Ludovico had published this whole proof very well typeset while we were writing this, still that work was written for the purpose of competition, and I doubt whether it would survive, since it includes almost nothing else of note. And if there are some notable items, they stand apart, and are not of a single kind, thus requiring matter. Hence I would reckon it worth the effort, in order to prevent the demise one day of such a rare &941 instance of subtlety, to add this here once more. But how? With brief proofs, in case those who recoil from Geometry get bored.

Thus to start with, the fourth proposition of the first of his *Elements*[45] will be proved as was done by Euclid, as it does not need the assistance of any other previous proposition. Then the fifth:[46] so far as proof goes, it only needs the fourth (which we will call the first, as we will call the fifth the second). For extending lines, the size of the circle proposed to us will be enough, since lines can be extended straight as far as desired. Then there will be a third one for us, which is

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écrits actuellement perdus": P. ver Eecke, *Proclus de Lycie: Les Commentaires sur le premier livre des Éléments d'Euclide* [Bruges: Desclée de Brouwer, 1948], xix). But elsewhere, for the study of astronomy and planetary motion, he described a theory of the helix which Copernicus later acknowledged. (See L. Siorvanes, *Proclus* [Edinburgh: Edinburgh University Press, 1996], 298–99, who also provides biographical details.)

[43] On Lull see n. 10 above.

[44] Lodovico Ferrari was Cardano's most brilliant pupil, who had come to him originally as a servant lad and became an accomplished mathematician. He played a leading part in the public dispute with Tartaglia over the priority of a solution of the general cubic equation.

[45] "If two triangles have the two sides equal to two sides respectively, and have the angles contained by the sides equal, they will also have the base equal to the base, the triangle will be equal to the triangle, and the remaining angles will be equal to the remaining angles respectively, namely those which the equal sides subtend."

[46] "In isosceles triangles the angles at the base are equal to one another, and if the equal straight lines are produced further, the angles under the base will be equal to one another."

written as the eighth[47] by Euclid in the first Book of his *Elements*. When another triangle is placed opposite on the base, and a straight line is drawn from vertex to vertex, it is accepted (as Proclus too shows in the third book from the second proposition), and from the opinion of the general mind,[48] that the triangles have uppermost angles and the sides containing them equal; so, from the first proposition, the triangles are equal, and the triangles can be transposed, as Euclid in his fourth proposition accepts.

Our fourth will be the ninth of Euclid in his first book:[49] that is the book I mean, till I insert mention of some other book. So with the lines containing the angle made equal in relation to the prearranged width of the compasses, I shall draw two circles at the given compass width, with centres at the ends of the lines, intersecting each other at a forward[50] and reverse[51] angle, and with lines drawn to that intersection from the centres of the circles, and then from intersection &942 to intersection from the third of these, and from the definition of a circle the proposition is instantly evident.

But if anyone is so misguided as not to accept that circles intersect each other elsewhere than at an angle, then by drawing a straight line between the ends of the lines containing an angle, we will repeat circles at each end so often till ultimately they either intersect each other or touch. By the second and first of these propositions we will succeed, and finally by the third the angle in question is cut in two, by a straight line drawn from the angle to the opposite intersection of circles.[52] We shall make our fifth the tenth of Euclid,[53] the power and the figure having been shown on the previous precedent.

The sixth will be his eleventh;[54] from either direction, from a given point, we will take the measure of the circle's breadth. Both have been divided into two according to the fifth,[55] and the parts to be united at the point will be half

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[47] "If two triangles have the two sides equal to two sides respectively, and have also the base equal to the base, they will also have the angles equal which are contained by the equal straight lines."

[48] "animus communis."

[49] "To bisect a given rectilineal angle." But just above, Cardano has stated that his fourth will be Euclid's eighth, not ninth as here.

[50] "proposito."

[51] "adverso."

[52] This is confusing, partly because two sets of numbers for the propositions are now offered: that of Euclid and that of Cardano. The construction in Euclid's I. 1 involves intersecting circles and that in his I. 2 involves touching circles. Euclid's I. 9 bisects an angle and Cardano has just above numbered it his own fourth, though slightly earlier he has allocated that place to Euclid I. 8.

[53] "To bisect a given finite straight line."

[54] "To draw a straight line at right angles to a given straight line from a given point on it."

[55] Proposition; Euclid I. 10.

the width of the compasses, and the width will be that of the two linked; hence, using the ends of that line as centres, where the circles intersect each other, a line drawn to the given point will be perpendicular from the third of these. Thus we will establish the thirteenth,[56] fourteenth,[57] and fifteenth[58] of Euclid, as the seventh, eighth, and ninth of these, since they now depend here on no others except proved ones.

The Part of the Thirteenth

The tenth proposition will be this: when two unequal lines are proposed, touching each other, cut off from the longer a length equal to the shorter. This is part of the third proposition of Euclid;[59] but [590]Euclid proves it also about non-linked lines.[60] To prove this, let the angle &943 they contain be divided by an infinite[61] line; later, I will draw a circle with centre on the end of the shorter line, a circle to fall on the end of the lesser line, and it will cut the larger line at the point of equality with the lesser one. Then after transposing the triangles whose vertices are on the point of conjunction of the stated lines, you will allow sections of the circles with the lines, in such a way that the base dividing in the middle is common to each, according to the method handed on by Euclid in his fourth proposition[62] of the first book of the *Elements*[63]—unless the given lines turned out equal; then the part will be equal to the whole, which is impossible. But if you say that a circle with its centre on the end of the lesser line does not reach the middle one, let these angles be split in two according to the fourth proposition[64]—often enough to touch; then with the proof repeated the proposition will stand as before.

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[56] "If a straight line set up on a straight line makes angles, it will make either two right angles or angles equal to two right angles."

[57] "If with any straight line, and at a point on it, two straight lines not lying on the same side make the adjacent angles equal to two right angles, the two straight lines will be in a straight line with one another."

[58] "If two straight lines cut one another, they make the vertical angles equal to one another."

[59] "Given two unequal straight lines, to cut off from the greater a straight line equal to the less."

[60] Euclid I. 3 does not require the lines to share any common point.

[61] "indefinita."

[62] See n. 45 above.

[63] The previous sentence is identifiable as part of Euclid I.3, and this one may relate to Euclid I. 9, which Cardano has numbered 4.

[64] I.e. Euclid I. 9, "To bisect a given rectilineal angle."

Now that we are transposing the triangles, it is not permissible to do that for building anything; it would nearly be equivalent to the drawing of a line parallel to a circle,[65] but only in theorems, to reach the proof.[66]

The Part of the First and Eleventh

The eleventh will be to lay out an isosceles triangle on the given line; we will divide it in two, we will raise a perpendicular from the point of the section according to the sixth,[67] and the proposition emerges according to the first when the triangle is finished.[68] From this and the previous one, without circles, by Euclid's method, we will prove his second,[69] which will be our twelfth. But from this Euclid's &944 third[70] will be proved generally by his method, which will be the thirteenth of these.

The sixteenth of Euclid,[71] and the five following ones, will be proved as they are laid down by Euclid, and with us will have the place of the fourteenth and the five following ones, since so far they need no others from us except those already proved.[72] On a similar basis the twenty-sixth, and the four following, will take over the place of our twentieth, and the four closely following ones. Our twenty-fifth will be the twenty-third in Euclid, which is proved thus: you will make lines equal to each other containing an angle according to the given width of the

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[65] "circuli aequilatationi"; this is defined in *L&S* (citing Vitruvius 9.7.3) as "the space between two parallel lines of a circle"; but the meaning there appears to be what I have indicated here. In any event, the reasoning here is obscure.

[66] This sentence appears first in 1560. Some modification of the wording of 1550 is introduced here in 1554 in the comparison of Euclid's and Cardano's marshalling of the theorems of geometry after this point in the text.

[67] "per sextam." "If in a triangle two angles be equal to one another, the sides which subtend the equal angles will also be equal to one another."

[68] This is a curious proposition: Euclid I. 1 constructs an *equilateral* triangle on a given straight line, and here Cardano uses Euclid I. 11 (his own 6) to perform what is now required.

[69] "To place at a given point (as an extremity) a straight line equal to a given straight line."

[70] "Given two unequal straight lines, to cut off from the greater a straight line equal to the less."

[71] For the text of subsequent propositions of Euclid, reference may be made to the Euclid translation included in the Bibliography.

[72] Anyone examining the original Table here will note that it has been corrected in the version now shown: the left column presents Euclid's order, and the right column Cardano's, and in the original the right column has slipped upwards one place. Also, in the left column "10" has been amended to "16." I am indebted to Dr Jackie Stedall for pointing out these corrections.

Pars	*primae*
2	12
3	13
16	14
17	15
18	16
19	17
20	18
21	19
26	20
27	21
28	22
29	23
30	24
23	25
6	26
24	27

compasses. Then with a straight line extended beneath, it will be smaller, by the eighteenth, than both sides of the triangle containing the given angle. We will therefore cut off on this base, by the thirteenth, an equal line on the line, with this given pricked out. Then making endings again on both sides, we will draw circles on centres of the cut-off line, which will cut themselves off from the eighteenth, as I said. Then with lines extended from the common section of circles to the ends of the underlying line, it will now be clear that the angle on the given point is equal to the subject[73] angle. Then we will prove the sixth in the position of the twenty-sixth very easily from the thirteenth by a proof which reduces its contradictory to the impossible. But I wish to show it by a true proof: so I will create another triangle from the previous one, with a base equal to the base, and angles above its base equal to the angles above the base of the proposed triangle. Then placing base to base, &945 from the first of these propositions offered by Euclid, it will come about twice, from the common opinions of the mind,[74] that by placing them the other way round, the sides are shown to be equal.

With that done, just as the seventh was proved by Euclid from his sixth, the twenty-seventh will be proved from the previous one. The[75] twenty-fourth and twenty-fifth of Euclid follow this, and the thirty-first of Euclid; but his first will be proved by us thus in the thirty-second place, by making an equilateral triangle near the compass's breadth in the same way as Euclid, but at the ends of the given line, with two angles equal to those of the triangle from the twenty-fifth of these, and so from the thirty-first there will be a third to the third,[76] but from the second of these the angles of the preceding triangle are equal, and therefore those of the second triangle. Therefore, from the twenty-sixth, the second triangle set up on the given line will be equilateral.

The thirty-third will be the twelfth of the first of the *Elements*. I draw from the given point according to the thirtieth of these a parallel[77] line, and then according to the sixth derived above, I draw a perpendicular from the same point, till from the same part it reaches the given line; when it meets it, it will lie perpendicular, from the twenty-third, although the previous one is in a straight

[73] "propositus."

[74] "per communes animi sententias."

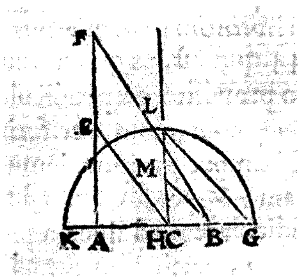
[75] The first dozen words here are a revision first appearing in 1560 of the fewer words of 1554.

[76] Euclid (I. 31) runs: "Through a given point to draw a straight line parallel to a given straight line." What the phrase here means is unclear.

[77] "aequidistantem."

line.[78] Since nothing else is supplied except what has been proved, after this it will be open to us to go ahead right to the last proposition of the first book, leaving behind only the twenty-second.

The whole second book follows on the same basis, apart only from the last proposition. Also the first sixteen of the third book, and the first part of the thirty-first proposition[79] of the same, which &946 we shall call its thirty-fourth; when a line is drawn from the centre, according to the second of these, it is agreed that the top angle is equal to the two included that lie equally above the base. And since these three are equal to two right angles, from the thirty-first, one must agree that the top one, lying in a semicircle, must be a right angle. Further, by following the same method by which they are proved here, the remaining parts of this proposition can be evident. Also, as the whole fifth book does not depend on the others, it will be proved readily on the reasoning derived from



Euclid; then the twelve opening propositions of the sixth book of the *Elements*, since they only need what has been proved. Now the thirteenth of the sixth book should be proved instead of the thirty-fifth; after linking the lines AC and CB to a point in a straight fashion,[80] according to the thirteenth, I shall draw AF according to the sixth, which I shall make double the width of the compasses, according to the thirteenth, and after drawing BF, I will draw CE according to the thirtieth, parallel to BF, and will make CG equal to EF, and CK equal to EA, according to the thirteenth.

Since from the fourth of the sixth book of the *Elements*, the proportion AF:AB is as AE:AC, then from the nineteenth of the fifth book of the *Elements*, AE:AC is as EF:CB, hence KC:AC is as CG:CB, according to the seventh of the same fifth book of the [591]*Elements*; and hence from the fourteenth of the same, if KC is greater than AC, or equal to it, or less, correspondingly CG will be greater than, equal to, or less than CB. So since KG is equal to AF, divided in the middle at H, according to the fifth a semicircle will be described of the proposed size, because AF was double its breadth, according to the sixth. So &947 I raise a perpendicular CM, and after drawing GL from the section of the circle, and perpendicular, we will draw BM parallel to it according to the thirty-sixth;[81] thus it is accepted that CM is proportionately midway between AC and CB; for

[78] "cum prior iam sit rectus."

[79] Proposition I.31 opens: "In a circle the angle in the semicircle is right, that in a greater segment less than a right angle, and that in a less segment greater than a right angle."

[80] "secundum rectitudinem."

[81] Reading "trigesimamsextam" with 1550 and 1554 instead of the "trigesimam mediam" of 1560.

as has been proved, KC:CA equals CG:CB; hence KC:CG equals AC:CB; but from the fourth of the sixth book, CG:CB equals LC:CM , but from the eighth of the sixth book of the *Elements*, and the thirty-fourth of them, KC and CG are in mean proportion,[82] so likewise is CM in mean proportion to AC and CB. From this is reckoned the last proposition of the second book of the *Elements*, which is the thirty-sixth.

On the same basis we will complete by Euclid's proofs all the propositions of the sixth book of the *Elements* except the last. Then we will set about the seventeenth of the third book of the *Elements*, which will be the thirty-seventh. So after drawing a straight line across the circle through the centre, I shall take a middle line according to the thirty-fifth among the whole,[83] which runs from a point right to the internal circumference and the circumference adjoining it outside, then above the end of the line found by erecting a perpendicular according to the length[84] of the radius of the circle, to which a tangent[85] is drawn from the specified[86] point, I close the triangle.

&948 So when a perpendicular line has been drawn from the end to this contained angle, or to the similar one opposite, in accord with[87] the twenty-fifth proposition, I make an equal angle in the centre towards the selected point, from which a straight line drawn to the end of the line that makes the angle will be tangential,[88] I mean when it touches the circle. For from the sixth proposition of the second book of the *Elements* and the forty-seventh of the first one, a line from a point to the centre will be equal to a line finally drawn which is directly opposite; from the first of these propositions, the angle at the base adjoining the circumference is a right angle, and from the sixteenth of the third book of the *Elements*, the line when extended is tangential.

All the rest of the third book except the fourteenth and thirty-third follow from those already proved. In the twenty-fourth we shall prove the location of the centre as Euclid did; it is not possible to complete the circle, as this is out of accord with the assertions;[89] still, we shall use it,[90] because it is only needed in circumscribing circles or in drawing circles without the finding of a centre, as we will show. In the thirty-third too of the third book we shall complete as many angles as we want above the given line, because if a circle were drawn above it, they would all lie within its circumference. We will complete this with the help

[82] "in media proportione."
[83] "inter totam."
[84] "quantitatem."
[85] "contingens."
[86] "propositus."
[87] "ex."
[88] "contingens."
[89] "repugnet promissis."
[90] Reading "illi" instead of the "illa" of 1554 and 1560.

of the thirty-fourth, which is proved without the thirty-third in your selected circle, then from the twenty-fifth above the established line. These will therefore stand for us in place of the thirty-eighth and thirty-ninth, just as the last of the sixth book of the *Elements* stands for the fortieth.

Later, we will prove the first of the fourth book of the *Elements*, which will &949 be our forty-first. From the twelfth of the sixth book of the *Elements*, a line established to be of the width of the compasses set out at A, so as to be of the radius of the circle in which a line is to be inscribed to the inscribing of a line,[91] then with A located in the circle available to me, I complete a triangle of two equal sides, and an angle in the centre of the circle available to me, which a line subtends equal to A, and I make it according to the twenty-fifth in the centre of the selected circle. And so it will be agreed from the thirty-first of these that triangles are similar when a straight line is drawn below their radii, hence in the case of the radius granted to A, like that of the radius related[92] to the line drawn below, from the fourth of the sixth book of the *Elements*, it was of the sort of the radius of the circle related to the proposed line, and so the line drawn below is equal to the proposed one.[93]

After this, the twenty-second [*sic*] of the first book of the *Elements*[94] requires proof, though for Euclid's purpose it was not needed, but he added it simply on account of the twenty-second, [*sic*] which has already been proved above.[95] So let three lines A, B, C be proposed, under a condition added at the same place,[96] and I assume a circle granted to me, whose diameter is DH, and its centre is E,[97] and let A be greater than B, and B greater than C, and from the twelfth of the sixth [book] of the *Elements*[98] already proved, let DE:EF[99] be equal to A:B, and EF:FG be equal to B:C; and because B and[100] C are assumed as longer than A, the whole EG will be longer than ED, and so the point G will fall

[91] "ut semidiametri circuli, in quo est linea inscribenda ad lineam inscribendam." Obscure.

[92] "propositi."

[93] In effect, Euclid IV. 6 provides a method of using compasses to draw a chord of a circle which has a pre-arranged length (less than the circle's diameter, of course) defined by that of a line provided elsewhere.

[94] Euclid I. 22: Out of three straight lines, which are equal to three given straight lines, to construct a triangle; thus it is necessary that two of the straight lines taken together in any manner should be greater than the remaining one.

[95] It is not clear what theorem is meant here.

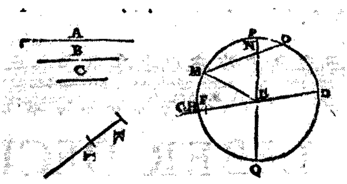
[96] The "conditio" in Euclid I. 22 is that any pair of the proposed three lines shall together be longer than the third line.

[97] The text here runs, "cuius dimetiens DH, et medium eius DE."

[98] Euclid VI. 12: To three given straight lines to find a fourth proportional.

[99] N.B. in the diagram F appears to be defined by a small line across the diameter CD close to C.

[100] I.e. *plus*.



outside the circle; from the same twelfth of the sixth book of the *Elements*, GF:FH is equal to DF:K, and to K let L be also taken, equal to GF; then DF:K is equal to L:FH. But because HF is the smallest of the four quantities of a single proportion, DF will be the largest, and the whole &950 DH is greater than the whole K plus L, from the twenty-fifth of the fifth book of the *Elements*.[101] Therefore, from the previous forty-first,[102] we will place K plus L in a circle however we like, so that it can be MO, and from the thirteenth[103] I will make MN equal to L, and NO will be equal to K, and I shall extend ENP from the centre straight opposite to Q, and again from the same centre, EM. From the sixteenth of the sixth book of the *Elements*,[104] the product of K and L, that is, the product of MN and NO, is equal to the product of DF and FH, because K and L were in mean proportion between DF and FH; and from the thirty-fifth of the third book of the *Elements*,[105] the product of PN and NQ is equal to the product of MN and NO; so from PN to NQ is as much as from DF to FH. So as PQ is equal to DH, NP will be equal to FH, and EN equal to EF; EM is equal to ED, and FG equal to L, and L equal to MN, so FG is equal to MN, so the triangle EMN[106] consists of three lines equal to DE, EF, FG, and of the proportion A to B to C; then suppose there are equal angles M and E above A, from the twenty-fifth,[107] and the triangle EMN will be similar; hence from the fourth of the sixth book of the *Elements*,[108] the proportion of A to the remaining sides is as EM to EN and EM to MN, but was the same as A to B and A to C; &951 therefore from the eleventh of the fifth book of the *Elements*

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101 Euclid V. 25: If four magnitudes be proportional, the greatest and the least are greater than the remaining two.

102 No book of Euclid's *Elements* has a "forty-first" except X, and X. 41 appears irrelevant.

103 I cannot trace a relevant "thirteenth."

104 Euclid VI. 16: If four straight lines be proportional, the rectangle contained by the extremes is equal to the rectangle contained by the means; and if the rectangle contained by the extremes be equal to the rectangle contained by the means, the four straight lines will be proportional.

105 Euclid III. 35: If in a circle two straight lines cut one another, the rectangle contained by the segments of the one is equal to the rectangle contained by the segments of the other.

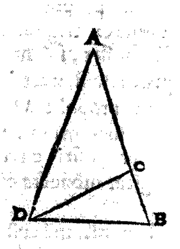
106 1550 (not 1554 or1560) persistently refers to M as A here, and since its woodblock figure is barely legible, this is unsurprising.

107 Euclid I. 25: If two triangles have the two sides equal to the two sides respectively, but have the base greater than the base, they will also have the one of the angles contained by the equal straight lines greater than the other.

108 Euclid VI. 4: In equiangular triangles, the sides about the equal angles are poportional, and those are corresponding sides which subtend the equal angles.

and the ninth of the same,[109] the sides B and C will be equal, which was what was proposed.

When this forty-second has been proved, we will prove the forty-third, which will be the tenth of the fourth book of the *Elements*. Suppose there is a line AB which I divide (as the eleventh of the second book of the *Elements* shows) at C, and by the previous proposition, I make a triangle on AB of which one side is equal to AB, and suppose there is another side AD equal to AC, and suppose there is a side BD. And so, since AC is in mediate proportion between AB and BC, from the seventeenth of the sixth book, it will also be equal to BD, and in mediate proportion between AB and BC; so when the line DC is drawn, there will be a triangle BAD and another triangle BDC with a common angle B, and with the enclosing sides in the same proportion as the sides,[110] from the sixth of the sixth book of the *Elements*. Hence BD is equal to CD, and thus DC is equal to CA, and from the second of these propositions, the angles CDA and A are equal, and from the thirty-first, DCB is equal to both, and so is double in relation to A.



But by the second of these, DCB is equal to B, and by the same, B is equal to ADB, therefore ADB as well as B is double in relation to A, which was the proposition. It is clear from this that all the propositions of the fourth book are proved, except that it will not be permissible to circumscribe or inscribe a circle, but only to find a centre, and to construct actual equilateral and equiangular figures, and the whole[111] teaching of Euclid has now been covered right to the close of the sixth or ninth book.

To let us reach the end of the remaining books, we will prove the one that is &952 forty-fourth, to erect from any point on the proposed diameter a perpendicular to make contact with the circumference of a circle; by the thirty-fifth, we will find one mean in proportion, and by the sixth we will extend this perpendicular to the proposed line from the given point, and it[112] will touch the circumference of the circle whose proposed line is the diameter, from the proof of the thirteenth of the sixth book of the *Elements*, which Euclid employs. And when we wished to prove the forty-fifth (which runs like this: to set up on a given line a triangle having a right angle at its top, and this angle looking down on[113] the

[109] Euclid V. 11: Ratios which are the same with the same ratio are also the same with one another. And V. 9: Magnitudes which have the same ratio to the same are equal to one another; and magnitudes to which the same has the same ratio are equal.

[110] "erit trigonus BAD et BDC angulo communi B, et lateribus continentibus proportionis eiusdem laterum,"— the obscurity here stems partly from a diagram which does not accord with the verbal description.

[111] Reading "tota" with 1550 and 1554, , not the "tot" of 1560.

[112] Reading "pertinget" with 1554, not the "pertingent" of 1560.

[113] "respicientem."

given line, with one side of the triangle consisting of the assigned line, which is less than the first one), we will mark out the circle already granted to us, and with the diameter derived from the twelfth of the sixth book, we will link a line to it below, to which the diameter is to have the same relation as the first line has to that side. So this line will be less than the diameter of the granted circle, so that from the forty-first, we will locate it within the circle, and we will fill out the triangle. So from the twenty-fifth, we will make an angle above the first line at its extremity, and from the thirteenth, we will make this line extended equal to the asssigned second line; consequently, from the sixth of the sixth book of the *Elements*, when the triangle is completed, it will be like the first one and right-angled. When this has been found, we will reach the end of all that Euclid wrote, as well as of what Hypsicles the Alexandrian added,[114] without any obstacle. But these (as they stand here) and similar discoveries were made to show off one's talent, and were virtually useless.

[114] Hypsicles the Greek mathematician (ca. 190–120 B.C.) wrote on regular polyhedra, and composed an addition to the *Elements* of Euclid, its so-called Book XIV, on inscribing regular solids in a sphere. For further details see http://www-history.mcs.st-and.ac.uk/Biographies/Hypsicles.html (accessed 29 March 2010).

[592] &953 Book XVI
On the Sciences

Those sixty properties of figures which I now propose to insert here are not without usefulness.[1] A circle is made by the motion of an inflexible thing fastened at its other end—just as is a straight line by the motion of[2] a plane remaining in the same place, as in the case of a wheel upon a fixed thing—this is how rods[3] are made. They are also made by straight extension. So it is clear from this that a straight thing comes before a circular one in technique, but a circular one comes before by nature. These are the ends, and consequently the contrary of a circumference, and it is of a much smaller circuit. All the other lines are intermediate between the straight and the circular, and (so to speak) composite between these. So the basis for the circle and the straight shapes is definite, but that of the others is indefinite, except so far as one depends on the generating of the other, as a cone's surface is on a straight line, and a parabola's[4] on a cone's. From surfaces no surface except a circular one is said to be generated, much less any of the rectilinear bodies. They become rectilinear, they are not generated so; the simplest thing is what is rounded, such as the sphere among the bodies, and the circle among the surfaces. The circle has twelve properties. In this first property, lines cutting each other establish parts that are in the same proportion.[5] And the angle contained by their intersection, with the angles established in the circumference above each arc equally included, is [593]equal. The quadrilateral inscribed in it[6] always has two angles located opposite, equal to &954 two right angles.[7]

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[1] The following eight sentences first appear in 1554.

[2] "sicut recta motu plani eodem loco consistentis"—movement *of* a plane apparently and not over or in or on one.

[3] "regulae"—or "rulers."

[4] The parabola is described later in this Book, at 959 (1560).

[5] This is probably equivalent to Euclid *Elements* III. 35: "If in a circle two straight lines cut one another, the rectangle contained by the segments of the one is equal to the rectangle contained by the segments of the other."

[6] I.e. in a circle.

[7] This is Proposition 22 of Book III of Euclid's *Elements*.

And two rectangles of the same, existing from opposite sides, are likewise accepted as equal to the rectangle of the diameters of the quadrilateral.[8] The two opposite sides of a quadrilateral inscribed in a circle are equal to the two remaining opposite sides. It is indeed the most capacious of the figures in respect of its circumference. And all the figures within it are the most capacious of those that can be held within the same sides; the figures in this equilateral are also equiangular. It has a point in its middle from which all lines extended to the circumference are equal. If a point is fixed outside it, as many lines as are drawn to the facing part of the circumference will, when drawn to the outer part, make a rectangle equal to the square[9] of the tangent from the same point.[10] But if a diameter is extended outside by any chosen amount, but is intersected by another diameter in the centre at right angles,[11] then if from its end a quarter part of the circumference is divided into the same number of equal parts, through the last of these let a straight line be drawn to the one which lies nearby externally at right angles to the diameter—this will be adjacent to the diameter and equal to all the straight lines from the circumference of the divisions with points drawn perpendicular onto the underlying diameter, right to the facing part of the circumference; all of these lines are drawn parallel, as is evident, to the diameter which is external.

But if from the same end of the diameter any number of lines are drawn, either inside or outside, some of them outside to the adjacent area, some &955 inside to another part of the circumference, the rectangles in the outer areas from the whole of the line into the intercepted part of the circle's circumference and in the internal areas from the whole into the part intercepted by the diameter remaining and lying at the straight lines, when a circle is inscribed in the square, are always equal.[12] These are features common to the circle, the hyperbola, and the ellipse.[13]

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[8] Heath (*Euclid's Elements*, 225, in comment on *Elements* Book VI. 16) expresses this much more clearly: "The rectangle contained by the diagonals of any quadrilateral inscribed in a circle is equal to the sum of the rectangles contained by the pairs of opposite sides"; he calls it an important lemma given by Ptolemy, and supplies Ptolemy's proof of it; the proof involves an inspired construction and the working out of proportions between the sides of similar triangles; the rectangles never get drawn as such.

[9] "quadrato."

[10] This is Proposition 36 of Book III of Euclid's *Elements* (Heath, *Euclid's Elements*, 73–75), which Heath translates as: "If a point be taken outside a circle and from the point there fall on the circle two straight lines, and if one of them cut the circle and the other touch it, the rectangle contained by the whole of the straight line which cuts the circle and the straight line intercepted on it outside between the point and convex circumference will be equal to the square on the tangent."

[11] "ad rectos [angulos]."

[12] This appears tortuous and unclear.

[13] "defectio," a Latin equivalent of the Greek word Cardano uses later in this Book: "ellipsis."

A perpendicular drawn from the tangent onto a diameter lying directly towards the point from which the tangent is drawn divides the parts of the diameter[14] in the same proportion which the whole line from the point from which the tangent is extended on its way to the circle's centre, right to the other part of the circumference, possesses to the external part. The half diameter also is in mean proportion between the line which runs from the centre to the external point and the one which runs from the centre to the place where a perpendicular falls from the place of the tangent above the same diameter. When two tangents are drawn from the ends of a diameter, from the same points through the same point of the circumference mutually to another tangent, it will be the case that below the parts of the tangents limited by these last lines, a rectangle is contained equal to the square on the diameter.

When[15] a semicircle of fixed diameter is carried on round till it returns to its place, a body is formed which is called a sphere. But if the portion is less than a semicircle, a body is made like an egg, which is called an oval.[16] What is made from a larger portion has no name. But if a rectangular quadrilateral is rotated, a cylinder is formed, which can be called a column.

&956 But if a right-angled triangle is rotated in the same way with one of the sides containing the right angle fixed and the other extended on a plane, a right cone or pyramid is formed. There are three types of this, corresponding to the same number of distinguishing characteristics of the sides containing the right angle. If the sides are equal, a right-angled right cone is formed. If it is the larger side that is fixed, there is an acute right cone. But if it is the larger side that is rotated, an obtuse right cone is formed. I call a cone "right" to distinguish it from those whose summit is tilted and whose base is not a circle. So to start with: the whole base of a right cone is a circle where it rests on a plane, whether it is obtuse or right-angled or acute (or "oxygonius").[17] The topmost point of a cone is called its vertex. A line drawn from the vertex to the centre of the base is called the axis of the cone. And if a cone is split on its axis by a plane surface or (to be briefer) by a plane, the outline made from the plane which is contained within the cone is always an isosceles triangle, which the cone's axis always divides equally into two triangles; any of these is right-angled, and equilateral and equal and equiangular to the triangle from which the cone is formed.

So in the first figure let there be a right-angled triangle ADC, and by its rotation let a right cone ABC be formed, whose base is the circle BECF, from

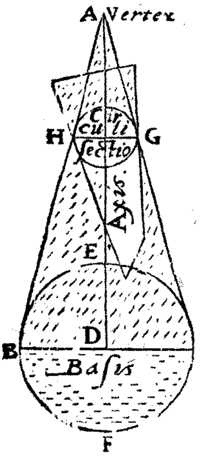
[14] "partes diametros"—it appears that here "diametros" is an adjective, as it can be.

[15] The material from here to [A] on 967 (1560) appears first in 1554.

[16] But not an ellipsoid; Cardano's "oval" is to some extent pointed at each end, which an egg normally is not. The Figures in this Book are often misleading through representing ellipses as linked pairs of arcs of circles.

[17] The Greek word "oxygonius" means sharp- (or acute-) angled.

its centre there is a line DA, which was the fixed side of the triangle, called the cone's axis,and its upper extremity is a point A, called the cone's vertex.[18]



If then a plane divides the cone upon[19] the axis AD, the part of the plane ABC held within the cone will be an isosceles[20] triangle &957 ABC, which clearly divides the cone equally. And it is clear that the triangle is divided by the axis AD of the cone into two right-angled triangles ADB and ACD, of which any is equal and equilateral, and equiangular with the original triangle ADC whose rotation made the cone. So if the side AD is equal to the side DC, it will be called a right-angled right cone, if AD is greater than DC, it will be called an acute right cone, and if AD is smaller than DC, it will be called an obtuse right cone. Yet this division is almost superfluous, since whatever they are called, they will be common features of every cone, so long as it is a right cone—whether it is right-angled or acute or obtuse.

So since a right cone (from now on, it will suffice to have called it just a cone, for brevity's sake, [594]since by "right cone" I mean just a cone)[21] will be divided by a plane standing at right angles on the triangle ABC, so that it passes through some point established outside the vertex, say G—then either the axis or the diameter of the figure confined within the cone will be parallel to the base while cutting both sides of the triangle, and then this figure &958 must be a circle, such as the circle GH in the first figure. I have written both "base" and "surface cutting complete circles" in the first figure, so that you could recognise them. But in the other later figures, the circles are too long to be delineated in proportion to their width, so that the cone and the sections transferred from a plane to the image of a solid are capable of better representation.

But if this plane passing through G and standing perpendicular on the triangle as it cuts the cone in two ways (this is necessary), also cuts both sides of the triangle ABC, and the diameter of that figure is not to be parallel to the cone's base, but (as it were) is tilted, a second figure will be created, called an ellipse. Suppose there is a cone ABCE whose triangle through the axis is ABC, and likewise a point on the surface of the cone and on a side of the triangle past[22]

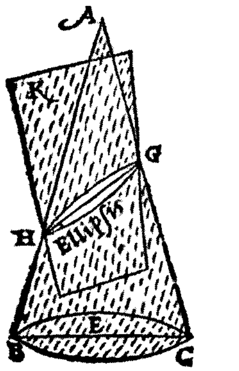
[18] The historic background to the treatment here of conic sections is provided in masterly detail by M. Clagett, *Archimedes in the Middle Ages*, 5 vols. (Madison: University of Wisconsin Press, 1964 [vol. 1]; Philadelphia: American Philosophical Society, 1976–1984 [vols. 2–5]), 4 (*Conic Sections*).

[19] "super."

[20] 1554 and 1560 both spell this "isoceles."

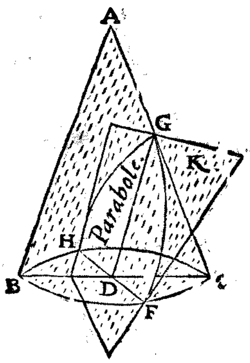
[21] Surely this is the wrong way round; by "cone" he means a right cone.

[22] "praeter."



the vertex, which I always call G; in the same way too a plane through the point G and standing perpendicular on the triangle ABC and dividing the cone into two parts is always to be called K. So if GH, which is enclosed within the cone and is part of the plane K, has an axis GH, as in the second figure, which divides both sides AB and AC yet is not parallel to the plane of the base BCE, but tilted either above or below it, let this figure be called an ellipse (that is, &959 "defect"),[23] because it cannot be infinitely extended as the two following figures can.

And if a figure is made on a plane K drawn through the point G and cutting the cone, and the figure's axis is parallel to the third side, this figure will be called a parabola. As in the case of the third figure, with the plane dividing the cone, let the figure enclosed in the cone (which is GHDF) have an axis G parallel to AB, the third side of the triangle, and then this figure will be called a parabola,[24] that is, "out of the region," because however much it is extended with the cone itself, it is always out of the region of the other side. Thus since the two preceding figures cut both sides of the triangle ABC, this and the next one do not cut the opposite side AB, as you can see. So if a plane standing perpendicular on the triangle AEC (as I always wish it to be understood, as also that it passes through a point outside the vertex) has not cut the side positioned opposite in cutting the cone, and yet is not parallel to the axis which is enclosed within the cone, (in this way it would be a parabola,) and would not cut the side positioned opposite within the cone, as I said, because it would be an ellipse, as mentioned, but would cut the side positioned opposite outside the cone, then it can be called a hyperbola, that is, excess,[25] because the angle contained by the axis of the &960 figure and the side of the triangle is greater in a hyperbola than in a parabola.



So let there be a plane cutting the cone in two ways, and standing at a perpendicular on the triangle ABC, and let there be a figure GHF, as in the fourth description, and a diameter of this figure GD; let it not cut the side AB within

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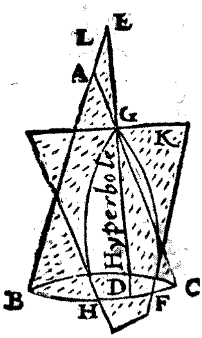
[23] The Greek word ἔλλειψις means a deficiency, a portion omitted, and this conic section.

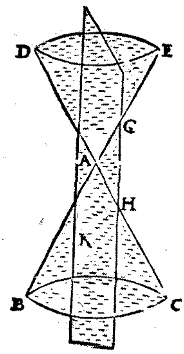
[24] The Greek word παραβολή, besides meaning "a placing beside," also means a comparison, a proverb, and this conic section.

[25] The Greek word ὑπερβολή, besides meaning "placing above or beyond," also means this conic section, and overstatement, excess, exaggeration.



the cone, nor be parallel to it, but let it be extended to meet it outside the cone at E, which is necessary, since it is not parallel to it, nor does it meet it within the cone: then this figure will be called a hyperbola, because the angle AGD is greater in it than in a parabola.

This makes it clear that in a cone, by the completing of a plane erected perpendicularly on the triangle and dividing the cone along its axis, and passing through the given point past the vertex, four figures are generated: a circle, an ellipse, a parabola, and a hyperbola;[26] and no &961 more kinds can be found from a single cone; it has a fifth with a plane dividing two equiangular cones positioned opposite each other at the vertex (you have an illustration in the fifth figure), and then there must be two hyperbolas; Apollonius[27] called these two "positioned opposite", as if there were two cones united,[28] ABC and ADE, likewise the lines BAE and CAD [595] are straight, and there are triangles through the same axis in the same plane, ABC and ADE, and points past the vertex marked in the one case as G and in the other as H, and a plane K drawn through both points perpendicularly on both triangles, and it is clear that it makes two hyperbolas, because the axes of the figures meet the opposite side outside the triangle—as they are like this in both planes, that is, those of the two triangles and K, those figures will both be hyperbolas, and Apollonius calls them "opposite."[29]



[26] "Ex his iam patet in cono perfectionem plani ad perpendiculum super trigonum conum per axem dividentis erecti, et per datum punctum praeter verticem transeuntis, quatuor fieri figuras, scilicet circulum, Ellipsim, Parabolen, et Hyberbolem, [*sic*] nec posse ex vno cono plura genera inveniri." Syntax clarified by reading "perfectione" instead of "perfectionem."

[27] Apollonius of Perga (in Pamphylia in Asia Minor), mathematician at Alexandria in the second half of the third century B.C., and about 25 years younger than Archimedes. His *Conics* expounded more fully and generally than his predecessors had done the fundamental properties of the conic sections. For further information see *Dictionary of Scientific Biography* and http://www-history.mcs.st-andrews.ac.uk/Mathematicians/Apollonius.html accessed on 26 Feb. 2008.

[28] If a cone's surface is regarded as generated by a line extending from a point indefinitely, it will be a single cone. But it is equally possible to regard it as generated by a line extending indefinitely and having one point (the apex) anchored while the line rotates round (normally) a circle. Then the cone generated is twin cones linked at the anchored point.

[29] For instance, "The asymptotes of opposite sections are common" (*Conics*, II. 15, on hyperbolas).

So from this it is clear that all these figures agree in this, that they are generated from a section of a cone or cones in two ways: by a plane erected perpendicularly on the surface of triangles, so as not to pass through the vertex of the cone; and because the sides of their surfaces are oblique lines; and because there cannot be more than these five. All these five have this in common, that when two lines that touch them directly have combined into one, and a straight line has been drawn from the place of their meeting to the opposite part of the figure or the part "opposite," the ratio of the whole line to its part lying outside the obliques is as that of the parts within the obliques &962 to the line that links the points of contact of the terminated[30] lines.

So since (as has been said) the third side of the triangle that divides the cone in the cone's axis must when extended meet the axis of the hyperbola outside the cone, the part of the hyperbola's axis between the hyperbola's vertex and the point of meeting of the triangle with the opposite side is called the "versa," and the point in the middle of the "versa," the centre of the hyperbola. And you have an instance in the fourth figure: A is called the "versa," and L the hyperbola's centre.

There are three salient features of a hyperbola, of which the first is, that if in each part of its periphery two points are taken, from which twin straight lines are extended to the asymptotes that do not touch and are parallel to each other, then the rectangles contained by the lines which emerge from below, and by similar pairs drawn from other points, will be equal to each other. The second feature is, that it is possible to find two lines in the same plane, of which one is straight, and the other a side[31] of a hyperbola, and they will always keep nearing one another, yet never touch. The third feature depends on the second, that it will be easy to find two lines which will always get nearer in the same plane, and even though they were extended to infinity, they will never be nearer than a thousand stades, for instance. With the second feature proved, if a line is taken parallel to the straight line and facing it a thousand stades away, what has been said will be obvious. So we will prove the second feature and though it is proved by Apollonius,[32] I would still like to use the proof of &963 Rabbi

[30] "terminatarum."

[31] I.e. one half of the curve.

[32] "The asymptotes and the section, if produced indefinitely, draw nearer to each other and they reach a distance less than any given distance" (Apollonius, *Conics*, II. 14).

Moyses of Narbonne[33] expounding the saying of Rabbi Moyses of Egypt,[34] in a book with the title "Guide for the Perplexed,"[35] the saying which ran, "There are some things that can be understood yet not imagined"; hence he concludes that the intellect differs from the imagination, on account not just of its novelty, but also of its ease and beauty.

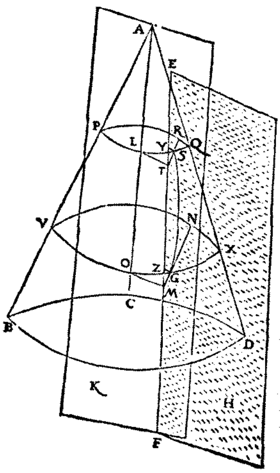
So let there be a cone ABCD; now I understand that there is no triangle intersecting it. But by ABD I mean the convex[36] surface of the cone, in which I extend AC from the vertex to the base. And let K be a plane surface touching the cone in the straight line AC; let this surface be understood as extended to infinity along with the cone's surface. I say first, that this plane surface cannot touch the cone's surface anywhere other than in the line AC; if this is possible, let it touch it at G, and I draw a circle through G parallel to the base BCD; so since the circle is in a single surface, points of contact of the plane K and the circle's circumference will be in a straight line, from the eleventh book of Euclid's *Elements*. So since this line already touches the circle's circumference in the line AC, from what Euclid proved in the third book of the *Elements* it will fall outside the circumference of the circle VXG, and so will not touch the cone at the point G. So I assume a straight line EF parallel to AC in the surface K, and so close to the straight line AC that the surface H drawn perpendicular to the surface K cuts the cone and its surface at points—call them S and G—and from what has been said it is evident that the part of the surface included from H by the cone

33 Clagett (*Archimedes in the Middle Ages*, 4. 1: 338) identifies this author as Rabbi Moise Provenzale (Narbonne is in Provence, in the south of France), active at Mantua in northern Italy in the mid-16th century, and quotes from his work composed in 1549 and published in Italian translation in 1550. However, there was a Moses of Narbonne who commented on Maimonides' *Guide for the Perplexed* but in the 14th century: see F. Y. Albertini, "Moses ben Joshua of Narbonne (d. c. 1362)," *Oxford Dictionary of the Middle Ages* 3: 1172.

34 This is not the Moses of Egypt, in the Old Testament, but Maimonides (also known as Rabbi Moses ben Maimon; born in Cordoba, Spain, in 1138 and died in Cairo in 1204) who was a Jewish philosopher and physician. His *Guide for the Perplexed* was written in 1190. For further details consult J.L. Kraemer, "Maimonides, Moses," *Oxford Dictionary of the Middle Ages* 3: 1069–70.

35 "Directio dubitantium." The passage of the *Guide to the Perplexed* here referred to is in the Kalam, tenth proposition (ed. Friedländer, 130): "Know that there are certain things which would appear impossible, if tested by man's imagination, being as inconceivable as the co-existence of two opposite properties in one object; yet the existence of those same things, which cannot be represented by imagination, is nevertheless established by proof, and attested by their reality." But Clagett (*Archimedes in the Middle Ages*, 4. 1: 336) has extracted from a 1520 Latin translation of the *Guide* reference to two lines approaching each other asymptotically, which "does not fall in the scope of the cogitation (!imagination)" (Clagett's own remark is in parenthesis here).

36 Though 1560 reads "connexam," with Clagett I translate "conuexam."



is a hyperbola, and the &965 line GS which is in the cone's surface is the side of the hyperbola. So it is agreed now that the side GS of the hyperbola is in the same surface as the line EF, that is, in the surface H; and that as those two lines are in the same plane H, they never touch each other; if in fact they do, they might do so for instance in the line AC, and thus AC and EF meet though parallels, which involves a contradiction; or else outside the line AC, and so since GS is always on the surface of the cone and EF on the surface K, then K would touch the cone outside the line AC, and we have proved the opposite of this. I simply say that since EF is a straight line and GS a side of the hyperbola in the same surface H, and they never meet even when extended to infinity, though invariably the more the cones are elongated from their vertex, [596]the closer they get to that. And it would suffice to show in one case, for instance, that G and M are closer together than S and T; then it will be clear that the further these two lines proceed, the closer they get. As an example, let the circle PSQ be taken, and let TSR be drawn, so as to reach the opposite part of the circumference; and likewise let MGN be drawn in the surface H, so that GN reaches the circumference of the circle VGX: and let LT and OM be drawn straight in the surface H, so that they touch the circles QLP and XOV,[37] because they are drawn from the place of contact; and because O and M are in the surface of the circle OXV (for M is the end of the line NM which is in the surface of the circle OXV), line OM will be in the surface of the same circle, and so LT will be in the surface of the circle PLQ.

But surfaces like this are parallel, &966 because each is parallel to the circle's base, and the lines OM and LT are both in the surface K and so parallel. And now LO and TM are parallel; they are parts of parallel lines, and so LT and OM are equal. And since they touch the circles PLQ and VOX, from Euclid's proofs in the third book of the *Elements*, the square on TL is equal to the rectangle TR.TS, and the square on OM is equal to the rectangle MN.MG, and the square on TL is equal to the square on OM, so the rectangle TR.TS is equal to the rectangle MN.MG.

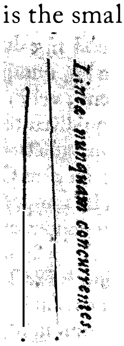
So from the proofs of the sixth book of the *Elements* of Euclid, the ratio of ST to GM equals that of MN to TR. But MN is greater than TR, because if there were drawn through N a surface parallel,[38] the surface would fall outside

[37] Respectively.

[38] To plane K.

R, otherwise it would meet K, because the diameter QP is less than XV,[39] and the surfaces of the circles are parallel, so ST is greater than GM. So SY and GZ are drawn perpendicular to EF, and the angles SYT and GZM will be equal, being right angles. Likewise, the angles STY and GMZ are equal, because ST and GM are parallel; they are both in the same surface (H), and in the two parallel surfaces of the circles; so from the thirty-second proposition of the first book of the *Elements*, the triangles STY and GMZ possess equal angles; so from the fourth of the sixth book of the same work, the ratio of ST to GM is equal to that of SY to GZ.

But as proved, ST is greater than GM, so SY is greater than GZ. But SY is the smallest line that can be drawn from the point S to the line EF, because



any line other than the perpendicular drawn from the same point to the line EF in any direction is &967 opposite to a greater angle than is SY, because it[40] is opposite to a right angle; so the point G is closer to the line EF than is the point S, which was what was to be proved. Most people fail in this final part, accepting a false chain of reasoning.[41] So I made a cone from a turnip, as Rabbi Moyses advises, and made the surfaces K and H from paper, and when the lines AC, EF, SG were drawn, the lines EF and SG turned out not to meet, as you can see at the side. But it is hard to describe these lines without working them out by this technique.[42]

[A] The ellipse has two properties:[43] the first is that its ratio to the surface of a circle is as that of a rectangle of the diameters of the ellipse to the rectangle of the diameters of the circle, which is a square.[44] The second follows from this,

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[39] 1554 and 1560 read "QP est minor XV" but Clagett (*Archimedes in the Middle Ages*, 4. 1: 350) translates as "QP>XV."

[40] The line from S.

[41] "paralogismus."

[42] Clagett (*Archimedes in the Middle Ages*, 4.1: 350–51) traces the origins of Cardano's proof, and shows that in fact it diverges significantly from that of Moise Provenzale. He also describes the later attack on this asymptotic problem by Francesco Barozzi (1586; for biography see www-history.mcs.st-andrews.ac.uk/Biographies/Barocius.html), which assesses Cardano's contribution in detail.

[43] "privilegia."

[44] That is, the ratio of the area of an ellipse to the area of a circle is that of the product of the ellipse's diameters to the square of the circle's diameter: if a is the lesser diameter and b the greater diameter of an ellipse, and d is the diameter of a circle, the two areas are $\pi ab/4$ and $\pi d^2/4$ respectively.

that the ratio of an ellipse to another ellipse[45] is that of the rectangles contained by their diameters.[46]

The parabola has six special properties. The first is, that the ratio of parts of the axis is in this: the ratio of the perpendiculars drawn from the points themselves to the circumference of the parabola is its square.[47] Second, since the perpendicular is equal to the part of the axis that will be limited at the vertex by the end of the same perpendicular, the perpendicular itself will be called the latus rectum[48] of the parabola, and this will always be having a proportion from the axis to the circumference like that of the perpendicular itself to the part of the axis that lies between the perpendicular itself and the section's[49] vertex; these perpendicular lines are called ordinates.

&968 So it is clear that to any part of the parabola's axis and to its perpendicular the same line is always subtended in continued proportion. Third, if a point is marked on it not on[50] the axis, and from it a tangent is drawn, and to this very many parallels from a circumference drawn to a circumference from the same contact point, a parallel to the axis will cut in equal parts all the lines drawn parallel to the tangent. Also, portions taken in any chosen way, with equal diameters, are also equal. And the area[51] is equal to a rectangle from the whole base multiplied by two out of three parts of the axis.

Sixth,[52] when three tangents cut the periphery of the parabola, two outermost ones[53] with the middle one cutting them, there will be a single proportion of three parts of the lines, that is, of the lower part to the upper, and of one upper one to the lower one, and of the middle one of these, which are terminated at the parabola's circumference.

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[45] That is, of their areas to each other.

[46] The 1550 edition includes here an account of the two special properties of the hyperbola, though the second is subdivided, but in 1554 and 1560 instead an account of three such features appears at 962 (1560).

[47] "If in a parabola two straight lines are dropped ordinatewise to the diameter, the squares on them will be to each other as the straight lines cut off by them on the diameter beginning from the vertex [i.e. the abscissae] are to each other" (Apollonius, *Conics*, I.20).

[48] Term normally restricted to twice the length of the ordinate passing through the focus of the parabola, not of any ordinate.

[49] I.e. the parabola's.

[50] "praeter."

[51] "superficies."

[52] Evidently the fourth and fifth are the immediately preceding unnumbered statements.

[53] "duas quidem extremas"; the syntax is irregular, since these words are in the accusative, not the nominative, case.

A spiral line has six special properties.[54] First, that when a tangent is drawn from its end, it meets a perpendicular from the starting point, always cutting off so much from the tangent, that it has a proportion to the circumference of a circle of the same order[55] following the order of a series of numbers. Hence it is clear that the portion of the original spiral from the perpendicular will be equal to the circumference of the first circle, and the perpendicular portion from the second spiral is double that of the circumference of the second circle, and the portion from the third spiral is triple that of the circumference of the third circle, and so on successively.[56]

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[54] Archimedes (*On Spirals*, trans. Heath, in *Great Books of the Western World* ed., 482–501, at 483–84, in his introductory letter to Dositheus; also in Sir T. L. Heath, *History of Greek Mathematics* [New York: Dover Publications, 1981], 64) wrote: "If a straight line of which one extremity remains fixed be made to revolve at a uniform rate in a plane until it returns to the position from which it started, and if, at the same time as the straight line revolves, a point move at a uniform rate along the straight line, starting from the fixed extremity, the point will describe a spiral in the plane. I say then that the area bounded by the spiral and the straight line which has returned to the position from which it started is a third part of the circle described with the fixed point as centre and with radius the length traversed by the point along the straight line during the one revolution. And if a straight line touch the spiral at the extreme end of the spiral, and another straight line be drawn at right angles to the line which has revolved and resumed its position from the fixed extremity of it, so as to meet the tangent, I say that the straight line so drawn to meet it is equal to the circumference of the circle. Again, if the revolving line and the point moving along it make several revolutions and return to the position from which the straight line started, I say that the area added by the spiral in the third revolution will be double of that added in the second, that in the fourth three times, that in the fifth four times, and generally the areas added in the later revolutions will be multiples of that added in the second revolution according to the successive numbers, while the area bounded by the spiral in the first revolution is a sixth part of that added in the second revolution. Also, if on the spiral described in one revolution two points be taken and straight lines be drawn joining them to the fixed extremity of the revolving line, and if two circles be drawn with the fixed point as centre and radii the lines drawn to the fixed extremity of the straight line, and the shorter of the two lines be produced, I say that (1) the area bounded by the circumference of the greater circle in the direction of (the part of) the spiral included between the straight lines, the spiral (itself) and the produced straight line will bear to (2) the area bounded by the circumference of the lesser circle, the same (part of the) spiral and the straight line joining their extremities the ratio which (3) the radius of the lesser circle together with two thirds of the excess of the radius of the greater circle over the radius of the lesser bears to (4) the radius of the lesser circle together with one third of the said excess . . ."

[55] "ordo."

[56] This is Archimedes' Propositions 18 and 19 (Heath, *History of Greek Mathematics*, 70).

Secondly,[57] a &969 tangent drawn from any point of the first spiral meets a perpendicular drawn from the start of the same diameter, cutting off from that a part of the same size as the portion of the circumference of a circle whose radius is a line from the start of the spiral line to a point on the tangent, enclosed between the first straight line of the spiral, which is understood to be in motion, and the place which the spiral reaches in its motion in a straight line with the site of the tangent. And there is a third special property: that the intervals of the spiral are like this: the first is of unity, the second of six of a kind,[58] the third of twelve of a kind,[59] the fourth of eighteen of a kind, and so on in continued addition of six of a kind.[60] The fourth special property is the proportion of any circle to the [597]interval of its spiral contained within the same spiral along with a straight line, and is as that of the square of the radius of the circle to the rectangle formed by the circle's radius into the straight line of the preceding spiral, with a third part of the square of the radius of the circle surrounding the first coil of the spiral.[61] The fifth special property is that the proportion of the sector of the circle circumscribing some primary spiral portion to the actual spiral portion terminated in the centre, and having the same angle as the sector, is as that of the square of the radius of the same circle to the rectangle from straight lines

[57] Archimedes (*On Spirals*, Propositions 18–19, trans. Heath, 492–93) proved that "If OA be the initial line, A the end of the first turn of the spiral, and if the tangent to the spiral at A be drawn, the straight line OB drawn from O perpendicular to OA will meet the said tangent in some point B, and OB will be equal to the circumference of the 'first circle'." Also, "If A' be the end of the *second* turn, the perpendicular OB will meet the tangent at A' in some point B', and OB' will be equal to 2 x (circumference of second circle)." And generally: if A_n be the end of the nth turn, and OB meet the tangent at A_n in B_n, then $OB_n = nc_n$, where c_n is the circumference of the "nth circle." The portion of Cardano's account (the "second property") now following represents the original Proposition 20 of Archimedes. I am grateful to Dr Stedall for making this point.

[58] "senarius." For the effective meaning here, see n. 60 below.

[59] "duodenarius." For the effective meaning here, see n. 60 below.

[60] Archimedes (Proposition 27) showed that if R_1 is the area of the first turn of the spiral bounded by the initial line, R_2 the area of the ring added by the second complete turn, R_3 that of the ring added by the third turn, and so on, then $R_2=6R_1$; $R_3=2R_2$; $R_4=3R_2$; $R_5=4R_2 \ldots R_n=(n-1)R_2$.

[61] Archimedes [Prop. 24] showed that the area bounded by the first turn of the spiral and the initial line is equal to one third of the "first circle" [$=\frac{1}{3}\pi(2\pi a)^2$, where the spiral is $r=a\theta$]. He also showed (Prop. 25, in the nomenclature of Heath, *History of Greek Mathematics*, 74) that "the area of the ring added while the radius vector describes the *second* (my italics) turn is the area bounded by the radii vectores $2\pi a$ and $4\pi a$, and is to the circle with radius $4\pi a$ in the ratio of $\{r_2r_1 + \frac{1}{3}(r_2-r_1)^2\}$ to r_2^2, where $r_1=2\pi a$ and $r_2=4\pi a$; the ratio is 7:12." Cardano does not mention the numerical value of the ratio.

containing a spiral sector, with the addition of a third part of the square of the difference of the same lines.[62]

The sixth special property is that when you cut off a sector with a smaller circle, a sector between two circles whose radii are increased by some rotation,[63] splitting the area of the spiral which runs from the end of the lesser line to that of the greater line, &970 it splits it into two parts, and the proportion of the outer of these to the inner is as that of the lesser radius with twice a third part of the difference of the radii to the radius of the lesser with a third part of the difference of the actual radii.[64]

It is one feature common to all rectilinear figures, that if individual sides are extended, all the external angles taken together, even if there were a thousand of them, are equal to four right angles. What depends on this is that all the angles held internally are equal to as many right angles as the double number of the sides, or of angles, with four deducted, which depends on the theory of the triangles into which the figure is divided. For the three angles of any triangle, taken together, are equal to two right angles, but an external angle is equal to the two internal angles lying opposite, taken together. Also, the area is equal to the product of half the sum of all the sides and the difference of any side from the same half, by multiplying everything at once, not linking them, so that three multiplications take place.[65]

It is a feature of a square[66] that its side lies in mean proportion between the aggregate from its diameter and between the difference of the same.[67] This occurs because the diameter[68] of a square makes a square double the square of which it was the diameter. The side of an equilateral and equiangular pentagon is

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62 This is Proposition 26 of Archimedes (Heath, *History of Greek Mathematics*, 73–74). 1550 and 1554 differ here for a few significant words.

63 "circumvolutio."

64 This is Proposition 28 of Archimedes (Heath, *History of Greek Mathematics*, 75) and can best be appreciated by reference to that *History* and the figure on that page.

65 The area is indeed the square root of s(s–a)(s–b)(s–c) where s = half the sum of the sides a, b, and c, but I cannot extract the whole of this meaning from the words ("Area etiam aequalis est producto ex dimidio aggregati omnium laterum, in differentiam cu iuslibet lateris, ab eodem dimidio omnia simul multiplicando, non iungendo, vt tres fiant multiplicationes"); the only part absent from Cardano's words is the square root. Maybe Cardano failed to mention it. This formula was elegantly proved by Hero of Alexandria (fl. about 10–75 A.D.); for details and references see Heath, *Euclid's Elements*, 2: 232, and http://mathpages.com/home/kmath196.htm (accessed 26 Feb. 2008). But it is not mentioned by Regiomontanus (*De triangulis omnimodis*, A.D. 1464).

66 "quadratum"—not simply a rectangle.

67 This cryptic expression probably means that the ratio of the sum of a diagonal plus a side to a side is equal to that of a side to a diagonal minus a side: i.e. if the side is unity, $(\sqrt{2} + 1) : 1 = 1 : (\sqrt{2} - 1)$, which is true for any positive value.

68 I.e. diagonal.

the greater part of a line divided according to a proportion having a middle and two ends, in comparison to a line &971 which is subtended by two sides of the same pentagon. And the side of a hexagon, provided as I said, that the hexagon is equiangular and equilateral, is equal to the radius of the circle circumscribing the same hexagon.[69]

The side of a heptagon and the line subtended by two of its sides and the line subtended by three of them together make up a triangle, if it were equilateral and equiangular, whose proportion of the aggregate from the side and the subtense is three to the subtense's two; it is as with two of the subtense to the side of the same figure, and again of the side and the subtense with two, to the subtense with three, it is as with three of the subtense to the subtended line with two sides of the same heptagon.[70] This will be proved below.[71]

Bodies and plane surfaces both have oblique properties; for instance, the "ambiens" of a sphere is four times the area of its maximal circle,[72] and of all bodies, the sphere has the greatest capacity in relation to its surface area.[73] It contains, and can be contained by, five bodies, which alone can have all their surfaces equal, and equal solid angles, and sides equal to each other.[74]

The parts of a sphere which are divided by a plane perpendicular to the axis have three special properties. The surface of any such part of the sphere is equal to a circle whose radius is a line from the vertex of the portion of the sphere to

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[69] True; each side of a regular hexagon subtends 60° at its centre, and the rest follows from these equiangular triangles.

[70] "Heptagoni verò latus, et linea, quae duobus eiusdem lateribus, ac linea, quae tribus pariter subtenditur constituunt trigonum, si fuerit (ut dixi) aequilaterus ac aequiangulus, cuius proportio aggregati ex latere et subtensa tribus ad subtensam duobus; est ut subtensae duobus ad latus eiusdem, ac rursus lateris, et subtensae duobus ad subtensam tribus, est ut subtensae tribus ad lineam subtensam duobus eiusdem heptagoni lateribus." I don't follow; however, in a regular heptagon of side unity, the line linking two adjacent angles is about 1.802 long and the line bridging 3 sides is about 2.247 long.

[71] In the translation of Johannes Kepler's *Harmony of the World* (61 and n. 201), it is pointed out that Cardano here gives a less substantial discussion of the heptagon, and in his *De Proportionibus* (1550) there is a more substantial discussion, and a further reference to it in his *Encomium Geometriae* (1535 as a lecture, printed 1562). It appears that Kepler was irritated by Cardano's view that the heptagon held a cosmological significance, seven being the number of the planets, while Kepler held a different view, reckoning that the number was six.

[72] If "ambiens" is the surface area, this is $4\pi r^2$, and the circumference is $2\pi r$—but the *area* of its greatest cross-section is πr^2.

[73] "ambitus."

[74] See Euclid *Elements* Bk III; these are the Platonic solids, from which Plato supposed the world was made: tetrahedron, cube, octahedron, icosahedron, dodecahedron. They can all be exactly inscribed in a sphere, and a sphere can be similarly inscribed in each of them, but in no other such solids.

the end of the circle that is the base of the same portion.[75] From this it is clear that the proportion of the surface parts of a sphere to the plane of the separates[76] is as that of the parts of the diameter divided in the same plane, since the sphere's diameter is perpendicular &972 to the plane.[77] The proportion of the bodily parts of a sphere which a single plane defines by dividing the diameter perpendicular to it is as that of the body produced by a square of the greater portion of the axis on a fixed line from the lesser portion, and by half of the axis at the body, established from a square of the greater portion on the line established from the half, and the greater portion of the axis.

This follows from the fact that a cone having the same base with a portion of a sphere, if its height has such a proportion to the height of the portion as has the aggregate from the height of the residual portion, and from half of the axis to the height of the same residual portion, will be the cone equal to the portion.[78]

It is clear from this that any sphere is four times the cone whose basis is its greater circle, but its height the midpoint[79] of the sphere's diameter.[80] Also, any cone is equal to a sector of a sphere (by "sector" I mean a body terminated at the sphere's centre, whose base is a portion of the sphere's surface; it is also clear that it comprises a portion of the sphere, and a cone having as its base the plane surface of the same portion),[81] since the cone's height has been the sphere's radius, and its base is equal to the surface of the sector, so the bases and heights will then be equal.[82]

In the case of a rectangular conoidal body[83] divided by a plane, the portion that is bounded by the apex is one and a half times the portion of a cone having

[75] It is not easy to adapt the words here to the fact that the surface of such a segment (not including the circle that is its base) is equal to the area of that circle multiplied by the distance from the segment's vertex to the centre of that circle.

[76] "separatarum."

[77] I.e. the area of the convex surface of the segment of a sphere cut off by two parallel planes is proportional to the thickness of the segment.

[78] 1560 reads "aequalis portioni," 1550 and 1554 read "aequalis axi."

[79] I.e. half.

[80] A right circular cone of radius r and height h has volume $1/3\ \pi r^2 h$, and a sphere of radius r has volume $4/3\ \pi r^3$. Hence if the cone has as height the sphere's radius, its volume will be one quarter that of the sphere, as stated.

[81] The definition of a sector appears first in 1560.

[82] This is related to the surprising but of course true "Hat Box" theorem of Archimedes, that equidistant planes cut off equal areas of a sphere's surface and of the surface of a cylinder of the same radius—near the end of an apple, the skin is very sloping and a relatively large area of it is removed by such a cut, while near the centre the diameter is large, and the portion of skin area cut off stays the same.

[83] This may also be termed a "paraboloid of revolution."

the same base and axis.[84] Further, rectangular conoids &973 preserve the proportion to each other, if they have been divided by a plane, of the axis of the same parts squared. But when an obtuse-angled conoid[85] is cut by a plane, the proportion of the part bounded at the vertex to the portion of a cone possessing the same base and portion of axis will be like that of a line existing from the part of the axis of the conoid portion with triple of the line which runs from the centre of a hyperbola or of the slanting line of the form to the same portion of the axis, with double of the same which runs from the centre of the hyperbola.[86]

But there are four special properties of spheroidals: when it[87] is divided by a plane through the centre, it is divided in equal parts, and any portion will be double the cone having a base and axis equal to the portion of the spheroid itself.[88] If the spheroid is cut through the centre, in some way the proportion of that [598]part to a cone having the same height and base is like that of the half axis with the axis of the remaining portion to the same remaining portion of the axis of the other part of the spheroid. From which the fourth special property is clear, that when a spheroid and a portion of a sphere retain the same or equal height and base, they will themselves in turn be equal.

Then cylinders have two special properties. A cylinder is thrice the volume of a cone that has the same height and base. But a cylinder will be one and a half times a sphere with a diameter equal to its height and a great circle equal to the

[84] This is the body generated by the rotation of a conic section—when e.g. a parabola, equation $y=\sqrt{x}$, is rotated round its axis, the surface is a parabolic mirror, and if its height is unity, the volume contained is $\pi/2$. Now the volume of a cone of height and radius unity is $\pi/3$ (the formula is $\pi r^3/3$).

[85] This may also be termed a "hyperboloid of revolution."

[86] Archimedes (*On Conoids and Spheroids*, propositions 25, 26; trans. Heath, 473) showed that "in any hyperboloid of revolution, if A be the vertex and AD the axis of any segment cut off by a plane, and if CA be the diameter of the hyperboloid through A (CA of course being in the same straight line with AD), then (segment) : (cone with the same base and axis) = (AD + 3CA) : (AD + 2CA)."

[87] Presumably any one of them.

[88] Archimedes (*On Conoids and Spheroids*, Introduction; trans. Heath, 454) proposed for consideration: "why, if one of the spheroidal figures be cut by a plane through the centre at right angles to the axis, each of the resulting segments will be double of the cone having the same base as the segment and the same axis; while, if the plane of section be at right angles to the axis without passing through the centre, (*a*) the greater of the resulting segments will bear to the cone which has the same base as the segment and the same axis the ratio which the line equal to the sum of half the straight line which is the axis of the spheroid and the axis of the lesser segment bears to the axis of the lesser segment, and (*b*) the lesser segment bears to the cone which has the same base as the segment and the same axis the ratio which the line equal to the sum of half the straight line which is the axis of the spheroid and the axis of the greater segment bears to the axis of the greater segment."

cylinder's base.[89] These are the sixty[90] properties, outstanding in distinction and beauty and regard, of the geometrical figures both surface &974 and solid.[91] Yet it does not escape me that properties exist that are practically numberless, but cannot be compared with these for elegance, either because a proof of them has not yet been found, or because they cannot be understood by the criterion of their names alone, or because they are not related to equality but, so to speak, are wanderers; equality is an aim of geometry.

But suppose it shows something else, something greater, or well known?—greater is equally welcome, and well known means equal to what is known.[92] We can pursue this in three ways, and it is called the conclusion of the argument if it proceeds directly, or by negation when the respondent is constrained to something unwelcome. And by persisting power, as when the size of a parabola or of a sphere's surface is proved by Archimedes; and this is the method we normally use in the most searching discoveries.[93] This is double: the simple method is the one consisting in comparison of greater and lesser, as in determining the size of a sphere's surface; the other is from proportions, which have no end, as in the parabola's area. It is thus no wonder that geometry is of all sciences the most subtle; and though it starts out from the most obvious points, it has with good cause offered a bait enabling it to be taught first of all to children. It is extraordinary how fast it leads you on from a few most lucid axioms to highly obscure points. Similarly, it ascends rapidly from the most lowly to the most exalted issues.

However,[94] round Mathematics there cluster incomplete proofs and (in a way) fallacies. Incomplete proofs are found most in the kinds of proportions of imperfect nature, &975 such as the reflex proportion, which we invented.[95] And as it is the fruit of the most subtle study, and is common to all the equilateral figures that are inscribed in the circle, it will therefore be displayed here, particularly because we proceed with its aid to the discovery of the heptagon's sides, and we learn to use a method capable of disentangling.[96] So although it is out of sequence, many significant reasons lead us to append here the proof of this proportion. So since there have been three quantities, whose proportion in aggregate

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[89] $2\pi r^3$ compared to $4\pi r^3/3$. This is a corollary to Archimedes, *On the Sphere and Cylinder* II, proposition 34 (trans. Heath, 427).

[90] Sixty properties were promised at the head of Book XVI.

[91] "corporearum."

[92] "maius quidem aequalis gratia, notum autem cognito aequale."—syntax and meaning not entirely clear.

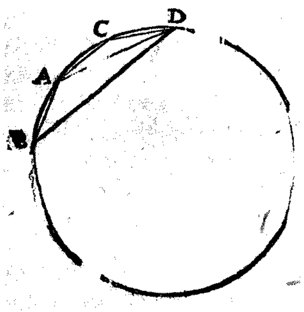
[93] "subtilissimis inventis."

[94] The material from here to [B] on 989 (1560) first appears in 1554.

[95] The details of "reflexive proportion" were defined in Cardano's *Opus novum de proportionibus* (1570; Maclean, *De libris propriis*, M148 [109]), Definition 20 and Proposition 66.

[96] "resolutoria."

of the first and second to the third was like that of the third to the second, this proportion will be called reflex. For instance, in numbers I take 9, 16, 20. Proportion 25, of the aggregate 9 and 16, to 20 which is like 20 to 16, it will be called reflex proportion.[97] For 9 is the first quantity, 16 the second, 20 the third. And if the proportion of the first of the aggregate and the third was beyond this, like that of the second to the first, it would then be called twice reflex. This proportion cannot be made plain by an example in numbers, but takes origin from the heptagon, as we will explain. So what I say is that simple reflex exists between two sides containing a double angle in some triangle, and the side facing the double angle, and the side facing the angle that is sub-double.[98] So let there be a triangle (or "triangulum"; this fine point is of no significance) ABC, of which the angle B is double &976 the angle A; I say that the proportion of the aggregate from AB, BC to the side AC which faces the double angle B is like that of AC to BC which faces the sub-double A. For from the ninth proposition of the first book of the *Elements*, I divide the angle ABC equally by the line BD. Then in the two triangles[99] ABC and BCD the angle C is common, and A is equal to CBD, since both are half of the angle B, and the angle CDB from the thirty-second of the first book of the *Elements* is equal to the angle B; hence these two triangles will have angles equal to each other. And accordingly, by the fourth of the sixth book of the *Elements* of Euclid (keep attending![100]), the ratio of AC to CB is as that of CB to CD. So the ratio AC to CD is double[101] that of AC to BC. But because the angle B is equally divided, by the third of the sixth book of the *Elements* the ratio of the sides will be that of the parts of the base; that is to say, AB to BC is as AD to DC. Hence from the combined proportion, on account of the eighteenth of the fifth book of the *Elements* the ratio of the aggregate AB and BC to BC is as AC[102] to CD.



But AC to CD is double AC to BC, so the ratio of AB and BC to BC is double that of AC to BC. Therefore from the definition of double proportion, the ratio of the aggregate AB and BC to AC is as AC to BC, which it was required to show. Let there then be one side AB of any equilateral figure inscribed in a circle, suppose one with thirteen sides, and let AD be the subtense on two sides of the same figure AC and CD, and let BD be extended because then AB is equal to AC, and also

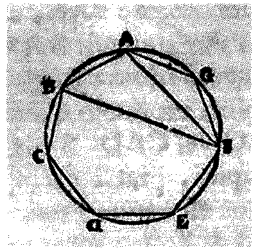
[97] 25:20 = 20:16.
[98] "subduplus."
[99] Reading "triangulis" with 1554, not the "triangulus" of 1560.
[100] "semper intellige."
[101] I.e. the square of.
[102] AC=AD+CD.

on the same basis CD; there will be individual arcs AC and CD equal to the arc AB, and so the whole arc AD is double the arc AB, from what is proved in the &977 third book of the *Elements* of Euclid, and the last of the sixth book of the same, the angle ABD is double the angle ADB; hence, from what has just been proved, the ratio of the aggregate of the sides AB and BD to the side AD is as that of the side [599]AD to the side AB. And similarly the ratio of the subtense to the four sides and the two sides, and of the subtense to the six sides and the three sides, and then the subtenses of others with the facing side. Thus the ratio is manifold in equilateral figures inscribed in circles, and those that are made up from them.

But no figure is better than that of an equilateral heptagon inscribed in a circle. So if a heptagon is marked out as ABCDEFG, and the subtense to the two sides AF and BF, and the subtense AB and AF, and as has been shown, the angle FBA is double the angle AFB, and the arc BCDEF is double the arc AGF, on the same reasoning—the angle BAF will be double the angle ABF, hence from the proved proportion BA and BF are to AF as AF is to AB; again, on the same reasoning AB and AF are to BF as BF is to AF. So this proportion is to be called doubly reflex.

Let us then suppose that AB is nine, having supposed that AF is sixteen and BF is twenty; if the proportion twenty-nine to sixteen were like that of sixteen &978 to nine, we would have the sides of the triangle ABF.

But since the proportion twenty-nine to sixteen is greater than that of sixteen to nine, we will set AF to sixteen,[103] and you will nearly have the position AB=200, AF=359, BF=448,[104] or by Aliza rule[105] with AF set, BF will be 1, R altered[106] 7/54 in 2 1/3 m 1/3[107] on a first estimate. With this situation, if a line is drawn from B through the centre, and where a line to F and to A falls in the periphery of the circle, you will have a quadrilateral with two diameters, and two sides of it and one of the diameters will be known. In addition, you will have two right-angled triangles, whose base will



[103] 1554 continues here: "... ac rem, addita AB, fiet aggregatum AB et AF viginti-quinque: plus reducatur in AF, fiet quadringenta: plus quadrato et rebus quadragintauna. Huius totius latus est linea BF, nam ipsa est proportione media inter aggregatum AB et AF et ipsam AF." and then includes further material before "With this situation ..."

[104] 9÷16= 0.5625; 200÷359= 0.5571; 16÷20= 0.8; 359÷448= 0.8013.

[105] Cardano wrote a treatise on this Rule; it is at *OO* 4:376–432 (Maclean, *De libris propriis* M149, [109]). It comprises 60 chapters and has some close bearing on the solution of cubic equations, on which see http://www-history.mcs.st-andrews.ac.uk/history/HistTopics/Quadratic_etc_equations.html But the origin of the word "Aliza" is obscure.

[106] "Mut."

[107] The immediately previous characters barely legible, and parenthesis is not closed.

be a diameter of the circle; hence setting aside the remaining topic[108] of the diameters, as the rectangle of the diameters is equal to the two rectangles that are formed from the sides of the quadrilateral facing each other, as shown by Ptolemy[109]—and from this, as we explained in the *Ars magna*,[110] by assembling lesser cases[111] the ratio of the diameter of the circle to AB the side of the heptagon will become known. So from this there is established a very choice example, without peer in the art of medicine, of the resolving[112] method, which Galen so often recalled.[113] The proposition is to inscribe a heptagon of known diameter in a circle; let us suppose this done, and let it be described above; so with the diameter provided, we need to know how &979 AB is to be worked out. To find it out, the ratio of AB to the diameter is to be found; for this to be done, the ratio to AF and FB will need seeking; so that you can get that, the proportion of the angles, which is all that is obvious, is to be discovered again. Then with that found, we must work out what this proportion determines between the sides. And this is called a twice reflex proportion. Since it is made from simple reflexes, we need to show it divided. And this is the aim of the resolving method.

The composite method, which we set forth in a demonstration of the sides of a heptagon, takes its start from this aim.But in this sometimes an error arises, if someone does not pay careful complete heed. An example of this is the following: let there be a circle ABC, a diameter BC in it, and on that a perpendicular DA. From A, I say, it appears that some line cutting BC can be drawn, such as AEF, so that CE is to EA as AE to EF, because CB can be increased as much as wished, which however is impossible; even if it were possible, we would not need the Aliza rule,[114] because BC has been laid down as 10. Suppose AE is 6; ED would immediately become known, and consequently EC and EB, and because the proportion of CE to EA is as EF is to EB, from Euclid's proofs in

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108 "res."

109 I cannot trace this (geometrical construction?) in the *Optics*; possibly it is in the *Almagest* or the *Tetrabiblos*. Note also Cardano's own comment a little later in the present Book at 1013 (1560): "I admire the first [Ptolemy] because I can barely understand him."!

110 This major mathematical work of Cardano's was published in 1545, and its ancestry from his earlier publications is set out in Maclean, *De libris propriis*, M69 [80] and earlier references.

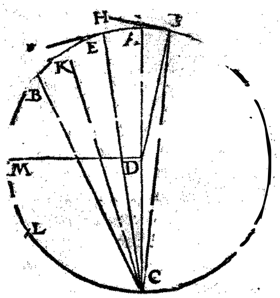
111 "capitulis"; on the meaning of this word in Cardano, see Witmer (*Ars Magna or the Rules of Algebra*, 30 n. 2), who points out that it can mean "case," "rule," "proposition," and even "equation."

112 Or "analytic."

113 I have not traced this reference to Galen, but he may have been recalling Plato; Plato's *Phaedrus* (265D–266B; Loeb, 553–55) discusses *diaeresis* and *synagoge* using love as an example; assembling its completeness constitutes *synagoge* or construction, dividing it into a good and a bad kind constitutes *diaeresis* or splitting up.

114 On the Aliza rule see n. 105 above.

the third book of the *Elements*, it would become the case that with the aggregate of the first and fourth quantities, and then the third, known, the quantities would become known. Therefore the case of the cube and of some equal number is known by ten things.The solution of the fallacy is, because AD is already &980 midway between the parts CD and BD, as it is known in itself, and the proportion AE to EF is always growing, more than that of CE to EA; thus the proportion of CE to EA is less than the proportion of AE to EF. However, wherever a point can be assumed in the circumference AB, it will always be capable of being extended, because the proportion of the part CB ended at the part extended from that point to the perpendicular is greater than the remainder of the part extended to the perpendicular AD, to which it is always equal, and the prior proportion is less increased than the later one, so they will always reach equality sometime. Thus fallacies arise in the universe, either when something is assumed in the construction of the problem of which we make no use in the proof, or when we employ an untrue but plausible starting point, or when we take something not proved as proved, or something as midway[115] which is not. All these occur more in contexts remote from the senses, as in the context of bodies, and of quantities of diverse [600]kind. The demonstration[116] of a falsity in the conclusion or the middles,[117] or the revealing of some defect from these words, indicates a fallacy. But a greater and more trying[118] fallacy arises in a different context:[119] I take for instance a circle ABC, and with CDA drawn through the centre, and CE, CK and CB equally distant one from the other, and also CG on the other side, the angles CBL, CKL, CEL, CAL on the circumference and contained by a straight line are acute; this is easily proved by drawing (for instance) DE from the centre, and EF a tangent; then FED is a right angle; but CEL is smaller than DEF, than the angle DEC, and than the angle of contact FEK; so CEL is acute; likewise CAL is acute, from &981 Euclid's proof in his Book III, and yet CEL is greater, as CEL is greater[120] than CKL, and CKL is greater than CBL;[121] this is evident, because



[115] "medium."

[116] "experimentum."

[117] "in conclusione vel mediis."

[118] "difficilior."

[119] "genere."

[120] Dittography here? But 1554 concurs.

[121] There is great difficulty here because without its associated word "angulus," in some case or other, a set like "CKL" cannot on its own possess the case (nominative or ablative) that would guide the reader, nor has it associated words like "than" in English which perform the same function.

all the contacts fall short in their angles, which are equal,[122] as we showed in the third book of our *Elements*;[123] and they fall short too in the right angle contained by the radius and the lines CB, CK, CE—these[124] are always greater the further the lines mentioned are removed from the line CA. Thus from the general mental feeling[125] the angle CBL is less than the angle CKL, and the angle CKL than the angle CEL, and CEL than the angle CAL. But the angle CGA is greater than a right angle; with GH drawn as co-tangent, and DG as radius, DGH will become a right angle, from the proofs by Euclid (as I mentioned) in the third book of the *Elements*, and the angle DGC is greater than the angle of contact, as is deduced there as a corollary. So with the angle of contact deducted from the right &982angle DGH and with DGC added, since the angle CGL is formed, from the general mental feeling CGL will be obtuse. So with the line CB passing gradually from B right to G, the angles contained by the circumference and the straight line will always be increasing, and gradually and by every kind of size right to obtuseness, as is clear—yet it will never become a right angle, as has been proved, because at A and before A it is always acute, and after A is obtuse; so the tendency emerges.[126]

A greater fallacy than this occurs of a different kind, and is like this. Some quantity grows continuously to more than double its size, or anyway to double, till it reaches a much greater quantity than another, such as a hundred times greater, and yet before reaching this extreme quantity, never gets equal to or greater than that smaller quantity. And this seems impossible, for two reasons. The first is that it should (as in the last situation)[127] &983 not grow equally, that is, to double, but to more than a hundredfold.[128] The second is that since that smaller quantity could not exceed that other minimal one by a greater magnitude than it has itself, with the minimal one increasing to double, it should finally exceed that quantity—and yet it does not.[129] What is more, a greater miracle follows; it is that I accept two quantities differing little in size, and yet with the

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[122] "quia deficiunt omnes angulis contactus, qui sunt aequales . . ."—obscure.

[123] Cardano did not publish a book entitled *Elements*; he may refer here to his *Novae Geometriae libri quindecim*, which examined Euclid's *Elements* in detail but does not survive as such; see Maclean, *De libris propriis*, M27 (58–59).

[124] masculine; cannot be the lines, might be the "contacts."

[125] "ex communi animi sententia"—a phrase unusual in mathematics!

[126] "intentum patet."

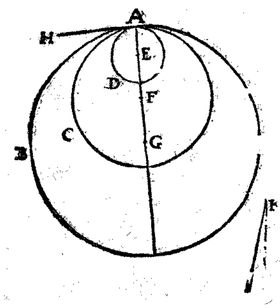
[127] "argumentum."

[128] On this point see n. in Book XIV at 918 (1560) above, and reference there to Zeno's traditional puzzle of Achilles and the tortoise.

[129] "oportet ut illa minima ad duplum crescente tandem superet hanc quantitatem, et tamen non superat." This is fundamentally ambiguous and it is hard to tell which is which here.

greater one doubling to infinity, and the greater[130] being divided in the middle to infinity, this smaller one when it grows will never exceed some part of this larger one divided through the middle.

I display all this by a single proof. I take some small angle (let it be K), but rectilinear,[131] which it is agreed can be divided equally to infinity, and this is easily achieved by extending the sides always further, so that the angle becomes more acute through continued division; its base will thus always get larger, and therefore the bases of the angles will be able to reach the same size. And then, with a line drawn from the place of division of the base to the angle, if the base is equally divided, so will the angle be.



Then I take three circles AB, AC, AD in whatever continued proportion you wish, touching each other at a point A; and from what was proved in Book three of the *Elements* by Euclid, their centres will lie in a single diameter, which is to be AEFG, and then it is certain that the angle BAD is greater than the angle BAC and CAD taken separately,[132] since the whole is greater than its part. Then either the angle BAC is equal to the angle CAD, and then the angle BAD will be double the angle BAC; &984or the angle BAC is greater than CAD, and the angle BAD will be more than double the angle CAD. Or if the angle CAD is supposed to be larger than the angle BAC, the angle BAD will be greater than double the angle BAC. It is then agreed that the angle BAD must be double, or more than double, larger than either of the angles BAC or CAD. Then let it be double, or more than double (for example) the angle BAC (for this is true)—then I take the two angles BAC and K.[133] Then I say that when the angle BAC is forever doubled, and the angle K is divided as far as you wish, even if you proceed to infinity, still BAC will never be able to enlarge to equal or exceed the smallest part of the angle K, though however the difference between these angles is minimal since the angles themselves are already minimal, for instance K a thousandth of a degree. For in the case of the smaller circles inscribed always on the same continued ratio in which DA stands to BA, the internal angle will be doubled that arises from the convex part of the circumference of the interior together with the concave part of the circumference of the circle AB, and this will go on till it reaches to the size

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130 1554 and 1560 have "maiore" here when the sense seems to suggest "minore," though I cannot follow the thought.

131 But presumably an angle in *spherical* geometry would not be rectilinear.

132 These angles are certainly not rectilinear in the diagram.

133 K appears a little earlier as the name of "some small angle," and evidently appears as such at the bottom right corner of the diagram.

of the angle which is contained by two straight lines at the circumference[134]— a size only less so far as there are two angles of contact;[135] let it be increased as much as desired by the smallness of the internal circle, and let a tangent AH be drawn to the greater circle, a tangent which must also touch the lesser one, since as has been proved, the diameter of the greater circle is the same as the diameter of the lesser one.[136] So if we arrange for AH to be a side of one part of the angle K, however small a part, the remaining side must fall within the circumference of the smaller circle, or a straight line could fall &985 between the tangent AH and the smaller circle, though Euclid's third book proved the contrary. So if a straight line falls within the circumference of the smaller circle, the angle of contact of the circles will become a part of the angle contained by straight lines. So since a part is [601]less than the whole, the angle of contacts, however great, will be less than the rectilinear angle, however small; which was the proposition to be proved.[137] So there appears to be a refutation of the first argument, that this angle is not equally increased by that movement of the line CB, but the closer it gets to A, the stronger is the case; accordingly it changes instantly from acute to obtuse without being a right angle. The proof of this is that in the progress of the first midpoint of the semicircle from C right to M, only the angle CML is taken up, and in the progress of the other midpoint of the circle, the angle CMA is taken up, from M right to A; but the angle CMA is greater than the angle CML in the angle CMA contained by straight lines, which is half a right angle. So there is a much greater increase in the angle contained by the straight line and the circumference in the middle of the semicircle MA than of CM. Things are on the same basis with the parts of the circumference MA assembled together. So the increment of the angle CEK over CKB is greater than the increment of CKB over CBL; and the increment of CAE over CEK is greater than the increment of CEK over CKB. So too it is the case that a line would pass through all intervening points[138] from B to K, but not from K to E, and much less so from E to A, and accordingly not from A to G. Thus the refutation of the first fallacy is evident.

But the second one is not refuted on the same basis, yet there are many &986 ways to proofs, and far more numerous ways to assumptions; in many of them it was well to know what was the case, as we have shown a little later in the generation of the number of the cubic solid. And that the greatest product from a part of any quantity is in the square of the remainder, when a third part of the quantity is multiplied by the square of the remainder; in fact we proved this in the

[134] "qui periferia continetur duobus rectis"— syntax unclear.

[135] "anguli contactus."

[136] This is puzzling, but might mean that they lie on the same straight line, as they do in the diagram: AEDFG.

[137] The celebrated "Quod erat demonstrandum"—"QED."

[138] "media."

twelfth book of the *Geometrical Elements*.[139] But the ancients were prepared to let this lie, so as to seem worthy of more veneration; this was of considerable benefit to us, and was also a help to them. Indeed, we have discovered principles in many cases through the whole of our technique.[140] I consider that Apollonius[141] achieved this, and Archimedes, but not Euclid nor any other philosopher; they had the help of what others had proved. It is said that Pythagoras of Samos[142] discovered the penultimate proposition of the first book of the *Elements*, and was so delighted by his discovery that he sacrificed an ox; but this is a barely credible tale, since Pythagoras actually refrained from any slaughter of animals. But it is certain that geometry was discovered through a proof of Archites[143] of Tarentum, a disciple of Pythagoras, about the discovery of two lines linked beween two others in continuous proportion, before the time of Euclid of Megara, and that it flourished with great distinction. It was no small matter that Euclid reduced everything to such a well-devised order, and filled in what was lacking.

But when the aim[144] is not so sure, discovery is certainly harder. The solution of some questions is extremely hard all through: &987 for instance, what could be the greatest proportion of double the third quantity to the aggregate of the first and fourth of a continued proportion; this is[145] in the lesser proportion one and a fourth times,[146] and in the greater, one and a fifth times. If we actually take 64 and 80 and 100 and 125, double the third quantity is 200, and the aggregate of the first and fourth is 189. The proportion 369/341 is less than 299/189. And 360 is double the third quantity, and 341 is the aggregate of the first and fourth in the "sesquiquinta" proportion, so that the quantities themselves are 125. 150. 180. 216.[147] This can be proved by multiplying 360 by 189, giving 68, 040.[148] This

[139] See n. 123 above.

[140] "tota arte."

[141] See n. 27 above.

[142] Philosopher of the 6th century B.C., born in Samos but emigrated to Croton in the toe of Italy and established a religious and philosophical society there; traditionally he was an eminent mathematician and contemplated the harmony of the spheres. But recently his status has been radically questioned. See W. Burkert, *Lore and Science in Ancient Pythagoreanism* (Cambridge, MA: Harvard University Press, 1972); and C. Riedweg, *Pythagoras, His Life, Teaching and Influence*, trans. S. Rendall (Ithaca: Cornell University Press, 2005).

[143] Not Archites, but Arch*y*tas of Tarentum, of the Pythagorean school, said to have founded mechanics and made other significant contributions, such as to the theory of music and of arithmetical and other progressions, in the first half of the fourth century B.C.

[144] "finis."

[145] "constat."

[146] "sesquiquarta"—but it appears to mean the ratio 4/5, 5 being 1 more than 4.

[147] Similarly, "sesquiquinta" is the ratio 5/6.

[148] "68. M 40."

is less than 68, 200.[149] So in such cases it is very hard to find a proof; the more so where the comparison of two quantities of different kinds, which attain no equality, takes place in a perfect kind. For as Archimedes showed, the ratio of a parabola to the triangle inside it is the precise "epitrita,"[150] which is covered in the fifth special property set out above by us.[151] So this was the starting point by which Archimedes was able to discover the proportion and mensuration of the parabola. It is clear from his proof that if this proportion had been applied to some ridiculous quantity incapable of description in numbers, Archimedes could not have proved it. Similarly the theory of the double relation of the sphere to the cone[152] is in his work, and further, in Euclid's, is the precise triple relation of the cylinder to the cone.[153] With these discoveries made, it was easy to state the theory of the parts in turn; those that are not linked in turn by a rational proportion have usually become known by the mean of two proportions.

&988 Hence it is not possible to find a square equal to a circle, and those who have tried seem not to have followed the proofs of Archimedes or Apollonius or Euclid; or if they have followed them, have not paid attention to them. For the whole starting point for discovery arises from arrangement,[154] and dispersal follows arrangement. But in arrangement the aim needs to be known, hence in the kind of different quantities their aim and theory requires knowing. But in the size of the circle, whether its surface is compared to the surface of a square or its circumference to its diameter, there is no proportion known of itself; Archimedes showed that the ratio of the circumference to the diameter is less than 22 to 7, but greater than three and 10/71. And that is to say, less than three and 10/70 but greater than three and 10/71, or between the proportion 1562/497 and 1561/497. But not in the case of surfaces: with a diameter of 7, the square inscribed inside the circle will be 24 1/2.[155] But the circle's area, as shown by Archimedes and

[149] Which is the product of 360 and 189 4/9. 1554 at this point includes nearly a page of mathematics absent in 1560.

[150] The ratio of 4 to 3; this seems to come out quite nicely for $y^2=x$ by integrating $\sqrt{x}\,dx$ from 0 to a, getting $2/3a^{3/2}$, and the triangle inside the parabola is $1/2a \sqrt{a}$, giving the ratio of 4 to 3.

[151] Although it is not explicitly numbered, this property is covered by the words, "And the area is equal to a rectangle from the whole base multiplied by two out of three parts of the axis," found at 968 (1560) above.

[152] See 972 (1560) in this Book; a cone with a base equal to the sphere's great circle and a height equal to its diameter has half the sphere's volume.

[153] A cylinder of radius r and height h has a volume $\pi r^2 h$ and that of the cone is $1/3\ \pi r^2 h$.

[154] "compositio."

[155] I.e. the area of a square inscribed in a circle of diameter 7 will be 24.5, which is correct.

ourselves, comes from half the diameter into half the circumference, so it will be 308½.[156] So the proportion is as 77 to 49, hence it is as 11 to 7.

But as has been said, the circumference is less than 22 by an imperceptible and not rational quantity; but the square inside is not changed, so the proportion of the circle to the inscribed square is somewhat less than 11 to 7,[157] therefore ridiculous and unknown. Very many of the ancients, and others of our own time whose number and names can barely be stated have tried, but the impossible thing has made the &989 lucidity of their talent look dimmer.[158] But this vain attempt stemmed from words of Aristotle whose interpretation erred. For instance, he [602]said he included the squaring of the circle with items that can be known but are not yet known; and if it is not known, there was no obstacle to make it incapable of being known. However, he did not actually say it could be known.[159] What happens is that it can be known in two ways: either in a way more obscure than when it is unknown, for instance through the helical lines that Archimedes uses, and he describes a straight line equal to the circumference of a circle;[160] or else through "translatio," which no one so far has dared to try, partly because of its difficulty, partly because of the unknown method of proof—some because they were confident of finding it by an easier method, others failing to try it because the writings of the ancients needed for this kind of proof were lacking. But since it does not attain a definite concept without the help of a proof, it cannot be conceived before proof, as sometimes happens by chance in some arithmetical problems. But so much for what concerns methods of proof, in which particularly we have taught the subtlety of the art of geometry.

[B]Arithmetic follows next, and its most subtle discovery is the art which we call the *Great Art*,[161] discovered and published by us; others have called it algebra, and it has manifold usefulness, sharpening the wits, discovering and disentangling the unknown sides[162] of quantities, and describing them by lines in accord with geometrical teachings, or by planes and solids; solving set problems and &990 puzzles, and being able to rebut wrongly solved ones, such as the

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[156] In fact the area of a circle of diameter 7 is *38*.485, not the 308 1/2 of 1560; the zero might be an interpolation in 1560, but cannot be in 1554, which uses Roman notation.

[157] It is close: 11/7=1.5706. . ., while the ratio of the area of a circle to that of the inscribed square is 1.5708 . . .

[158] On the history of squaring the circle, see http://www-groups.dcs.st-and.ac.uk/~history/HistTopics/Squaring_the_circle.html. Accessed on 26 Feb. 2008.

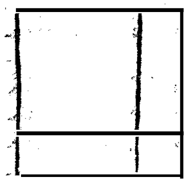
[159] The matter of what Aristotle said on this issue is discussed by Heath (*Mathematics in Aristotle*, 17–19, 33–36, 94–97) and at the website specified in the preceding note, and is rather more complex than Cardano here suggests.

[160] The approach of Archimedes is set out in the website mentioned in the preceding note.

[161] See n. 110 above.

[162] "latera."

side of the heptagon, a magnitude erroneously worked out by Bovillus,[163] and the equality of a straight line with the circumference of a circle fabricated by



Nicholas of Cusa[164] from a gradient, [165] and correctly rejected by Regiomontanus.[166] Everything depends on a very simple figure, which shows lines, areas, and bodies too, but also the six propositions following next after the fourth of the second book of the *Elements* of Euclid.[167] There is also another kind of composing a solid cubic number, appropriate for arithmetic, in which the kind of solution that arises from an arrangement[168] is clear: every cubic number is made up from the square of its side, and double the product of its side and all the preceding numbers right to unity; for instance, I take for instance 512, of which the side[169] is eight; so I say that 8 multiplied by itself makes 64, and by double the sum of the preceding numbers, which are 1, 2, 3, 4, 5, 6, 7, starting from unity, as you can see, and the double of this is 56, and the product from 8 and 56 is 448. They make the cube itself, that is, 512,[170] for 448 and 64 linked make 512.

From the start it used to appear that this could not be proved, but we have proved it by the method of resolution: since any cubic number arises from the square of a side upon its side, it will also arise from the same square of the side reduced by unity,[171] from the second theorem in the first book of Euclid's *Elements.*[172] &991 But the product of a square and unity is always equal to the

[163] Charles Bovillus, Charles de Bovelles, French mathematician. For biographical details see J. M. Victor, *Charles de Bovelles, 1479–1553: An Intellectual Biography* (Geneva: Droz, 1978).

[164] Cusa was near Trier in Germany. Nicholas (1401–1464) achieved a cardinal's position in the Catholic Church. For further details see for instance *Nicholas of Cusa: A Companion to His Life and Times*, ed. M. Watanabe et al. (Aldershot: Ashgate, 2011).

[165] Of closer and closer approach to the final value, probably; the word is "libramentum." Nicholas approached the problem of the circle's circumference as the limit of regular polygons and used it in his religious teaching to show how one can approach truth but never reach it completely.

[166] Johannes Müller of Königsberg, 1436–1476. For details of this German mathematician, see Ernst Zinner, *Regiomontanus: His Life and Work* (New York: North Holland, 1990).

[167] The following four paragraphs first appear in 1554, except the final sentence, which ia present in 1550.

[168] "compositio."

[169] I.e. cube root.

[170] Here, $8^3 = 8^2 (8 - 1) + 8^2$.

[171] I.e. $n^2(n-1) + n^2 = n^3$.

[172] The second proposition in the first book of the *Elements* is "To place at a given point (as an extremity) a straight line equal to a given straight line." The relevance of this here is not evident.

square, from what we have shown at the start of the sixth complete work, and even one's senses perceive that the product of a square and the side, with unity deducted, is equal to the product of the side and double the aggregate of all the preceding numbers; so with this proved, the proposition comes out.

This again needs resolution: as is the proportion of a square to double this aggregate, so is the proportion of a side to itself minus unity. So from Euclid's proofs in the sixth book of the *Elements*, the same value arises from a side multiplied by double this aggregate as does from a square multiplied by a side less unity. We should show this proportion once more, and this is the proof: because double this aggregate is always equal to the product of the largest number and one greater by unity, for instance double the aggregate of numbers up to 7 is 56, and this arises from 7, the largest number, multiplied by 8, the largest number plus unity.[173] So since from a side multiplied by itself comes the square on the side, and from a side multiplied by itself minus unity comes the well-known double,[174] from what Euclid has shown the proportion of the square of a side to double that is as that of a side[175] to itself with unity deducted, which we took as what was to be proved.

So this would be completely proved, except that it is not yet accepted that from any number multiplied by itself reduced by unity there comes double the aggregate of all the preceding numbers. The proof is like this: any two numbers &992 linked as equally distant from the mean, make twice the mean number, so all numbers from unity linked in series make as much as if the mean number were adopted instead of the number of their ends. But the greatest number includes precisely their order, therefore all the numbers in series taken from unity; linked, they make as much as their mean extended to the greater one. So double the aggregate of such numbers is equal to double the product of the mean and the greatest of them.[176] But the number greater than the largest by unity is double the mean, therefore from the greatest number into the greater by unity is double that aggregate of all the numbers from unity to the greatest number. And the mean is a limit of the arrangement.[177] But in what has so far been stated, what has been solved can be gathered by arrangement, and thus one can reach a proof of the theorem. And we will applaud some remarkable discoveries, like the

[173] The sum of integers up to a is a(a+1)/2.

[174] "et ex latere in seipsum detracta vnitate fiat illud duplum," evidently meaning what comes just below in the text: "from any number multiplied by itself reduced by unity there comes double the aggregate of all the preceding numbers."

[175] Reading "lateris," not the "literis" of 1560.

[176] Confusing: the sum of the n numbers starting from one is n(1+n)/2.

[177] "Est et medius quidam compositionis modus."

discovery of the sides by Michael Stiphelius,[178] copied by us into the first book of our complete work.

Following after these are musical discoveries, of the triple order of diatessaron[179] in the past, of which only one (the diatonic) is now known, and we have lost the other orders, either through oversight or through their difficulty.[180] Let us now explain very briefly the restoration of them made by us, and dealt with in the first and second books on music.[181] The chromatic occurs through modified[182] music, where not only in b fa b mi, but also from e la mi, and a la mi re a semitone is produced,[183] as in the case of the harp[184] particularly, but organs too are capable of music on this basis. &994 This mode appears very sweet in comparison with the diatonic kind, because of the frequency of the semitone; small intervals and ratios of the note impart attractiveness from the voices. The chromatic kind depends on the semitone, [603] tone, and one and a half tone, avoiding the double tone. These are small intervals, but smaller are the Enharmonics, separated by quarter tones,[185] and consequently sweeter than the chromatic harmony. To give you an example of this on the Phrygian pipes:[186] as we explained in the fifth book of the *Musica*,[187] its tremulous sound with a barely open aperture makes an interval[188] of semitones but hardly of whole tones; this perpetually

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[178] Michael Stifel (1487–1567) was a German mathematician who invented logarithms independently of Napier, using a totally different approach. See J. E. Hofmann, "Michael Stifel," *Jahrbuch für Geschichte der Oberdeutschen Reichsstädte* 14 (1968): 30–60; and http://www-history.mcs.st-andrews.ac.uk/history/Mathematicians/Stifel.html (accessed on 26 Apr. 2008). It is not clear in which of Cardano's works the material mentioned here was included, nor what its nature was.

[179] This is the interval between two musical pitches of 4:3, a fourth, and when multiplied by the diapente or fifth, 3:2, produces the octave (2:1).

[180] Material to [C] on 994 (1560) first appears in 1554.

[181] Cardano's *Musica* was started in 1549, and the first two books were entitled *Generalia praecepta atque principia*, and *Antiqua musica* (Maclean, *De libris propriis*, M83 [86]).

[182] "fictam."

[183] The A,B,C note names were already available well before the time of Cardano, but in different hexachords (partial scales) they corresponded to different notes. Thus in the "soft hexachord" b corresponded to fa and thus had a semitone below it (mi-fa) but not above it, while in the "hard hexachord" B corresponded to mi and thus had a semitone above it but not below it. Similarly for E and A. http://www.bbc.co.uk/dna/h2g2/A1339337 (accessed on 7 Jan. 2007) is very helpful.

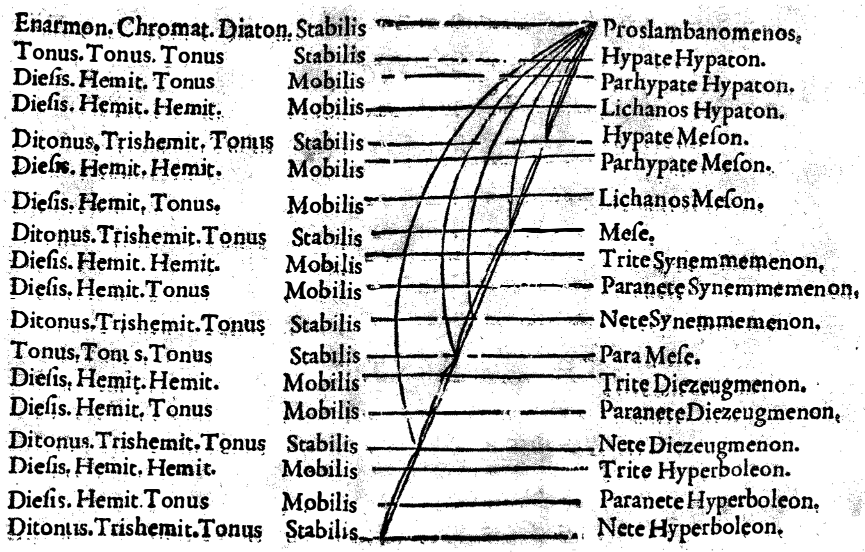
[184] "cheli," made of a tortoise shell originally.

[185] "dieses" (Vitruvius 5. 4. 3). The diagram in the text at this point displays numerous Greek names for musical tetrachords and intervals, and these can be interpreted by reference to Vitruvius, 5.4.3–5.5.5.

[186] "in elymis"; ἔλυμος is a pipe made of boxwood with a horn tip.

[187] On this work see n. 181 above.

[188] "diesim": properly means a semitone.



vanishing in the individual voices contributes an unbelievable attractiveness. Let us take another example on the harp (as organs are not capable of this). You know that on the harp the individual tones are separated by a semitone; you feel the tremulous voices which only exceed half the interval of a voice, and hence retain a quarter tone of such great sweetness;[189] just suppose the tremulous voices are interspersed with the individual strokes of the hurrying hand, and ponder how incredible a harmony you are about to hear. But on the harp one person will not be able to express himself. The lyre is more convenient, because it holds on to the voices more. But the ancients used to make instruments suitable for this, and among their strings intervals of quarter tones were set up. The end strings were located in the same places that make a concord, necessarily at every interval of a fourth. [C] But we added two sinews at the diatonic, one below the lowest, the other above the highest, so that the interval of semitones was established.[190] Not long ago, Nicolaus Vincentius[191] built a Monochord divided in quarter tones, so that he could divide individual tones into five and minor semitones into two.[192] In the common instrument there are &995 thirty shiny white keys, hence twenty one tones; eight lesser semitones in the lower rank. In the higher rank are twenty black keys, and 49 semitones. So this chromatic instrument has fifty keys, 49

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[189] "atque ideò diesim quantam dulcedinem retineant."

[190] The remainder of this paragraph together with the subsequent one first appear in 1560.

[191] Not traced.

[192] "in quinque semitonia minora in duo divideret."

intervals. Greater semitones 20, lesser ones 28, tones 21. So he reckons in those four ranks, of which two are higher, two lower, two of white keys and the same number of black ones, with the lesser tones divided into two quarter ones, so as to make 56; with greater tones in three, so as to make 60; in all to make 116, but 117 keys, then instead of an undivided tone (on which I spoke) five quarter tones and the same number of keys are present. The enharmonic monochord is of 121 voices, and with one more key than that. Certainly for convenience this is not a useless ratio, yet not totally precise. Lucretia too, a German girl at Bologna, added six strings to the harp, so that there would be 17 sets of three in the upper five ranks.[193] And the highest note,[194] the only one to be twin. The string that took the place of the lowest note[195] had two higher unison strings, and a third at the interval of an octave; the four middle ranks kept the unison concord of three strings.

This arrangement has a twin drawback: the restricted spacing, so that unless her fingers are slender and quite long, and the flautist excellent, like the one who during her seventeenth year could not be esteemed less than anyone, considerable difficulty and confusion are ahead. And such a number of strings when weakened could hardly stay long in definite tension.[196] &996But the difficulty added distinction to her, and the excellence of her art gave her a wonderful sweetness.

Since there are two extremes, and a midpoint, which is called the Tenor, in various voices (what was said about the diatessaron is only relevant to one) a fourth voice, the Altus, was added, and since it fills gaps, it excels the rest in sweetness; since something is artificially added to what was already perfect, it usually contributes to rich decoration. Hence with its wonderful art it suits all voices. It preserves uniquely the weighty tone, against which it often raises itself to the heights, at times changing (so to speak) to a weighty tone, it sinks into the depths, preserving with a loftier voice the whole harmony by contrary motion. Usually it plays at occupying the middle spaces. The outcome is that with its great importance it also draws out the nature and talent of a singer, and without[197] these nothing at all emerges.

[193] The number of strings in Renaissance harps varied, and no reference has been found to any unique contribution by anyone named Lucretia (*New Grove Dictionary of Music*, 8: 195–96).

[194] "nete."

[195] "Hypate" in a tetrachord.

[196] "Duplex habet incommodum haec constructio: spaciorum angustiam, ut nisi digiti sint graciles admodum longi choraulesque praestans, qualis illa erat quae cum decimum septimum ageret annum, nemini posthaberi posset difficultatem, et confusionem non leue sit paritura: tantusque numerus fidium eneruis uix possit in certa contentione diu manere." Sense and syntax unclear.

[197] Reading "si," not the "sit" of 1560.

Furthermore, singing the notes is easy; we call the notes Ut,[198] Re, Mi, Fa, Sol, La.[199] But producing the words is harder to do. Hence since children learn the notes first, they often have great difficulty in moving over to the words. This transfer happens in three ways.

The first is because a child learns by ear the fifth, the octave, the fourth, and the other concordant intervals, also the seventh and the ninth, and to produce them by his voice, and thus produces words and syllables as represented by[200] the size of the voices, which is quite difficult, since the sixth and the third are double, and cannot be produced without imagining the notes, and so if you substitute one for the other, you will be a semitone out &997 from the remaining voices.

The second way is to conceive in your mind—on whatever interval and line—what voice there should be and how large it [604]should be, and in this way you produce syllables as represented by the voice of the place. This way is better than the first, but since contrived quarter tones have occurred, and semitones or tones, it would not be satisfactory, and they would be produced with difficulty. The third way is best of all, to preserve in your imagination and voice the notes and the size of the voices, and with your tongue to produce the proposed syllable. And this, the best way, is also the hardest.

And so we will set about this in three ways: either with long practice, so that you gradually release the note, and produce the syllable in the notes, first in those of rather a long delay, and in unison; then gradually rising and descending, presently in unison, and a fifth and a fourth; also in concords which are called cadences, finally in other voices, and later transfer yourself to notes of a short delay. Another way is to learn to keep your tongue motionless, and thus to produce a voice without notes and syllables. Later, as represented all the time by just one syllable, such as the syllable A or E. Finally, concentrate on producing the syllables. This method acquires variety from the method of producing, as the first does from the actual thing or song. The third, better in my judgment, takes place with the help of someone else, who produces the notes while you are singing the syllables; in this way the size of the time and the voice will be preserved, and you will gradually progress with practice to what is very difficult.

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198 Doh in the sol-fa terminology later current. These were taken from a Latin hymn, "Ut queant laxis / Resonare fibris . . ." by Paul the Deacon, and supposedly applied by Guido of Arezzo. See R. Goldberg, "Guido Aretinus," *Oxford Dictionary of the Middle Ages* 2: 749.

199 Te was a later addition, to bring the scale back to Doh again, or more precisely, a counterpart for it was invented in the sixteenth century by Hubert Waelrant (c. 1517–1595), a Franco-Flemish composer and publisher, but it was not widely adopted at the time.

200 "sub"; translation speculative.

And there was another short cut[201] in the process of learning, so that anyone can learn very well without a hand;[202] this will occur if you have taught the student all the voices of one octave,[203] because &998 all the rest recur in the same orders, and thus the changes for the sounded keys, which always appear in three places because of the semitones. For when the basis[204] is altered, the keys are arranged with each other so that they are all reduced to two through resemblance, although they appear to be six: three called B soft, and the same number without that; if you have carefully noted them, you will reduce them to two only, on a basis not only wonderful and compact, but also quite easy; but this is treated at length in *Musica*, as I have said.[205]

After this comes the subject of Optics, of which the most subtle invention is that of clocks which display the hours by their shadows, and Vitruvius passed this on in his work, like much else.[206] This science of optics appears in the middle between the mathematical sciences and the very beautiful science of natural things, which we call Philosophy, with its very wide scope. We have written about the more important parts of it in our books *De arcanis aeternitatis*,[207] *De immortalitate animorum*,[208] and *De rerum varietate*.[209] Its most distinguished part is the one that explains how to foresee the nature of seasons and the temper of the air; it is of use to farmers, sailors, merchants, generals; and indeed for the whole human race it is both pleasing and health-giving. In fact the air's constitutions depend on two distinguishing characteristics, the one concerned with cold and heat, the other with moist and dry. In this kind there are five types: fair, which is also calm; windy, clouds, showers, hail or a fearful storm. Snow occurs during winter instead of rainstorms.

&999 The signs of winds are as follows from natural ordinances: a protuberance linked to the Moon, and when I have seen it, a very violent wind has ensued. A small cloud around one of two donkeys[210] presages winds to come from the same direction. Reddish clouds scattered over the whole sky, or a red Moon, and

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[201] "compendium."

[202] "sine manu" (i.e. the "Guidonian hand" teaching aid, on which see C.V. Palisca, "Guido of Arezzo," in *New Grove* 10: 522-26, esp. 525).

[203] "diapason unius omnes voces."

[204] "ratio."

[205] See n. 181 above; but the present topic has not been previously mentioned by Cardano.

[206] Vitruvius (9. 7. 2–7) supplies full details on how to create a sundial. 1550 and 1554 include here a sentence on the principles of these clocks, absent in 1560.

[207] On this work *On the secrets of eternity*, see n. at 5 (1560) in Book I.

[208] *Immortality of the Souls*, published in 1545; for details see Maclean, *De libris propriis*, M55. The word for "soul" used here is "animus."

[209] *The Variety of Things*. Completed in 1553; for details see Maclean, *De libris propriis*, M104.

[210] "nubecula circa asinorum alterum."

sunset among reddish clouds, fleeting clouds; the sound of bells which at one moment is heard very well, and at another is barely perceptible; when banners on the tops of towers move; spaces round the Moon that suddenly disappear: these reveal from where winds are to arise. But when a clear Moon sets or rises, and stars and the Sun setting white and clear, or if the Sun sets with a few clouds, and ravens croaking in flocks, as though for joy, and the little owl hooting persistently at night: these announce fine weather.

I do not believe that I can make out the signs of storms better than your poet, even if I have a free opportunity to speak; lt it be, so to speak, shackled in the lines of Vergil. First, he speaks thus in the *Georgics*:

> But when it lightens from the direction of the wild North, and the dwelling of the East and West wind thunders, and all the country is afloat with full ditches, and every sailor on the sea furls his wet sails, never did a shower assail the unwary, nor did the soaring cranes flee from it in the valley bottoms, nor did the heifer look up to heaven and catch the breezes with gaping nostrils, nor did the shrill swallow flit round the lakes, and in the marsh the frog croaked its ancient dirge. &1000 Often too the ant produced its eggs in its guarded chambers, pursuing its narrow journey, and the huge rainbow drinks the moisture, and an army of rooks moving from pasture in a long column clamours with close-set wings. Cayster's meadows now can see the diverse sea birds, and those that make search in the sweet swamps round Asia, vying to scatter the plenteous spray with their shoulders; now they thrust their head in the waters, now they run into the waves,[211] you see them exulting in the sheer[212] joy of relief. Then the crow, loud-voiced, summons the rain, and it struts on its own on the dry sand. And girls, carding their nightly stint, have no awareness of the storm, when they saw the oil sputter in the burning pot, and the rotting clots growing there.[213]

He added this with a definite indication that it is worth noting: "If it[214] has grasped the dark air with a dim horn."[215] Then this from the Sun:

> When, hidden in a cloud, he has decked his dawning rise with spots, and taken refuge in mid-circuit, beware of showers; for then the South wind presses from the height, threatening trees and crops and flocks. Or when his varied rays scatter under the light amid thick clouds, or when pale Dawn rises from the saffron bed of Tithonus, alas, the vine leaf ill guards the tender grapes. [605]Such plentiful hail jumps bristling and crackling on the roofs. &1001 It will help to keep this more in mind when he has run his

[211] Reading "in undas," with the modern text, not the "in uno" of 1560.
[212] Reading with 1550 and the modern text "incassum," not "in casum" with 1560.
[213] *Georgics* 1. 370–392.
[214] The Moon.
[215] *Georgics* 1. 428.

> course on Olympus; we often see changing colours stray over his face. Blue presages rain, fiery presages East winds; but if spots start to mingle with reddish fire, then you will see all boiling with wind and clouds. May no one bid me fare over the deep that night, nor snatch the rope from shore.[216]

Numerous haloes,[217] or haloes with strong colours; oxen licking their hooves and lowing and moving back to their sleeping quarters; hens spreading dust over themselves; mice squeaking; cats too grooming their heads with their paws—all these mean rain.[218] Clover senses coming storms in an extraordinary way, and contracts, curls up, and puckers; as it is very moist and fibrous, it contracts in cold and with thickness of the air, being already used to changing, and sometimes being astringent, sometimes expanding. Thus this will perhaps not occur in all of its types, and much less will be obvious in all cases or all the time. In all of them an unchanging width is required.[219] When there is no wind, lesser signs indicate clouds and a misty day. Strong winds with rain indicate hail; rain without wind is clear.[220] Frost will spoil vines and trees, and signal poor wine production, whenever the trees are putting forth shoots (in our regions this occurs in March, April, and the start of May) and in cold clear weather a full moon occurs, or at any rate if the Moon is full of light.

What the winds' fury can do prompts astonishment; winds rage on the mountain ridges so fiercely that when I was crossing the &1002 Apennines, a gust lifted my felt cap, and was carrying it off with its force[221] like an arrow from a "scorpio,"[222] and it nearly fell along with the rain onto the nearby villas, in the role of a portent. And it displaced the horse I was riding for a distance of two paces, so that I almost fell off. This persuades me that Poggio's[223] tale is not fabulous. It runs that winds that arose[224] overthrew a town called Borgetum, six miles

[216] Vergil, *Georgics*, 1. 441–457; on line 454 "maculae" is now read, not Cardano's "macula."

[217] "areae"; "Now, all light is round. Therefore, air also struck by light will go into this round formation. For this reason the Greeks called such shining lights 'threshing floors' [ἅλως, "area" in Latin], because generally the places set aside for threshing floors are round" (Seneca, *Quaestiones Naturales*, 1. 2; Loeb 1: 25).

[218] The following three sentences first appear in 1554.

[219] "Omnium constans latitudo exigitur."

[220] "pura."

[221] "impetus."

[222] A quickfire device for firing arrows.

[223] Giovanni Francesco Poggio Bracciolini (1380–1459) of Tuscany was a tireless traveller, author and collector of manuscripts (see M. Davies, "Bracciolini, Poggio," in *Encyclopedia of the Renaissance*, 1: 274–76).

[224] Reading "coortis" with 1550 and 1554 and not the "cohortis" of 1560.

from Rome, and a temple of Saint Rufina,[225] and a whole inn was shifted. So it is no marvel for it to rain frogs, minnows, stones—frogs and fish are shifted from mountain ridges by the wind's force.[226] And dust is shifted, which is condensed into stones by wind power. The evidence is that they do fall down not far from mountains, but as once occurred in the Alban mountain, and in valleys from nearby and higher mountain tops. Georgius Agricola mentions that at Chemnitz[227] tawny earth rained down with water. And in Swabia in 1534, the air kept marking clothing with a red cross; this was due to dust carried down with showers, and the cross shape appeared because of threads that reproduce the shape during weaving.

The eggs of tiny animals are also shifted, as are those of frogs and fish, which amid whirlwinds and rainstorms release animals that appear to rain down.[228] The evidence then is rather that this is due to decay and association with generation, rather than that they are shifted, since it happens more near mines and where pitch is plentiful than elsewhere. And it is more common for animals to rain down than wheat and the other cereals; still, these can be &1003 more easily shifted than actual animals. However, the account of Olaus Magnus[229] about the lemming[230] is remarkable: a kind of mouse, which in the North falls out of clouds in such numbers that it consumes all greenery, as locusts do. The field mice feed on it, and if the story is true that has been told elsewhere, it says that if opened up at once when it has fallen into its stomach, green grass shows—so that it[231] seems to have been transferred, not generated.[232] So it is no wonder if you keep an eye open for the causes; these things happen only in great wind movements.

Hence they were common in the time of the Roman Republic, because very powerful winds were also more common. Indeed, wind power used to be greater in the past, which is why[233] not only these portents[234] but also floods and inundations used to occur.

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[225] No doubt the Saint Rufina who was martyred in A.D. 287 during a persecution and buried at a point nine miles from Rome on the Via Cornelia.

[226] "impetus."

[227] Chepnicium, more usually spelled "Chemnitium." It is some 50 km south east of Dresden, in the south of Germany. Agricola was particularly associated with the place, and was sometimes called "Kempnicensis" for this reason.

[228] The following four sentences appear first in 1560.

[229] See n. to 637 (1560) in Book IX.

[230] "lemmare, vel lemmo." The statement is in Magnus, *Description of the Northern Peoples*, book 18, chap. 20.

[231] Masculine: cannot be the grass, must be the lemming.

[232] Evidently the meaning is that a lemming is effectively a mass of grass unaltered by a reproductive process.

[233] Reading "ob quam" with 1554, not the "quam" of 1560.

[234] Reading "monstra" with 1554, not the "nostra" of 1560.

These prodigies are dreadful because they result from excessive winds. But excessive winds arise from heat and severe dryness; hence they reveal betrayals, as the adage runs: "Excessive wind, betrayal thrives."[235] For either the cause of these winds arises from the stars, from the triumph of Mercury and Mars, and the more powerful constellations, the Dog, Arcturus, Orion; or else to draw us nearer to ourselves, a hot dry constitution which distresses weak heads drives them to betrayals, revolts, and slaughter. The common people usually have heads like these, because of their limited experience of things, and their intemperance, and this is why the worst of them are driven to crime. But it also happens that they are misled, and then it is believed that entreaties offered to the gods have proved effective.

And fishes are transported into fishpools, and to new waters, and new seeds to alien lands, as &1004 Theophrastus recounts about the laserwort plant;[236] hence the origin of fish and of new plants erroneously regarded as starting from decay. Evidence is that these phenomena appear particularly after storms, and never after prolonged clear weather.

In the same fashion[237] sometimes, though not often, a new and unknown kind of bird is transported from distant regions to ours, by the power of the winds that support them. Similar, but (so to speak) more divine is how medicine plans to use these patterns of seasons to predict bodily health and the kinds of disease, with which especially Hippocrates has dealt in the third part of his *Aphorisms*, and Aristotle in the first part of his *Problems*—with an extraordinary degree of subtlety.[238] For the present it is enough for me to set out the signs of a pestilence to come, as being more useful and obvious, and then with what the ancients have covered with less precision. Among these the first and most reliable and natural is not only a sign, but a cause: persistence of rains [606]at the end of spring or in summer, and without any blasts of wind, but with violent heat, and while it is not raining, the air looks cloudy and misty. Hippocrates described a constitution of this sort in the town of Cranon[239] long ago; an enormous and fearful plague

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[235] "Ventus immodicus, proditio viget." This adage cannot be found indexed in the large collection of *Adagia* assembled by Desiderius Erasmus, of which publication began in 1510.

[236] "Silphium."

[237] "ratio."

[238] The remainder of this paragraph together with the five subsequent paragraphs first appear in 1554.

[239] Crannon is in Thessaly, and is usually spelled with two Ns, but not by Hippocrates. "In Cranon in summer: anthrax. During the hot weather there was continuous violent rain. It occurred more with wind from the south. There were watery gatherings in the skin. When formed, they grew hot and caused itching, and then small blisters as though from burns rose up. They seemed like burns on the skin beneath" (*Epidemics* of Hippocrates, 2. 1; Loeb 7: 19). Cardano's somewhat divergent words correspond approximately

ensued, in which in addition to deadly fevers and tubercles and carbuncles, whole limbs shrunk by pestilence were falling off. As we said, heat and moistness are the begetters of corruption, when movement has not moderated them.

Another sign is often drawn from heaven, that is to say, when great solar eclipses occur, or comets &1005 or fiery flames are seen in the air. What can corrupt the air usually stems from excessive dryness and a bituminous vapour, though if nothing else ensues, the sign is misleading. In fact in 1531 and the subsequent years there were many comets, and from 1539 right to 1551 so many solar eclipses and great lunar eclipses were seen that more and greater ones are never recorded—yet Italy from 1524[240] to the present year 1559 has suffered no notable disastrous plague, indeed not even a trace of one. However, if trees are seen on fire, it is a surer sign of disaster to come, since it is our air that is already disturbed, not the air above, which concerns us less.

But if a sort of dusty air persists for some months, it presages a plague to come of a particular kind: the impurity that is drawn in impairs the heart, but especially the brain—since plague is made from water and air, the plague that is made from water makes for the heart predominantly; the one made from air makes for the brain. There is in fact no partition in the brain as compact as that in the lung, though the brain does breathe. The substance of the brain itself is softer than that of the heart, and more bloodless. The result is that in caves people first of all feel faint[241] through defect of the brain, then with the heart suffering too, they fall victim to syncope and death. So from this we can reach recognition of the causes, and thence of the kind of disease. And when bread exposed to the air picks up mildew overnight, you already have signs of corrupt air, and pestilence close by even if not yet started.

And when an old lady or girls have believed they see and hear gods &1006 proclaiming calamity, plague will follow; if they have seen and heard this, are the gods not lying? But if they are not seeing this, but mistakenly think they are seeing and hearing it, already black bile is abounding in blood through the bad quality of the air, which gets worse and creates plague. Again, rabies being common in dogs proclaims plague, because they are driven rabid either by water or by air; we have mentioned that rabies is generated by corrupt water. Similarly, wolves entering a town, and the persistent nuisance, indicates some rabies in them; excessive boldness signals rabies. So it is the causes driving them rabid that corrupt human humours and generate plague. In consequence too it sometimes happens that birds abandon their eggs and nests and underdeveloped chicks before a plague; all these are signs of predominance of black bile attributable to corrupted air or water. Sheep especially are overtaken by disaster before that time; being

to the sense of the *Epidemics* here, and no other such constitution for Crannon has been traced in Hippocrates.

[240] 1554 reads "1531."

[241] "lipothymia."

weaker and like human beings in nature, they suffer plague from the same causes as human beings. Also, an abundance of frogs, and of cockroaches[242] in walls occurs due to superfluous fatty moistness, and is damaging to human nature and brings destruction to it. And when worms and snakes appear, also moles, it occurs because they abandon their own nests because of the nuisance of vapour held below the earth, which rises to spoil the air by such a noxious change[243] that it can bring doom to snakes, and much more to human beings; practically nothing really underground can be &1007 healthy for a human being, and in general cannot be so at all. Hence what should happen is for such events to occur often and everywhere, and to persist and increase—then they do undoubtedly foretell a plague to come. If they catch this disease, even birds are an indication of a huge plague; Joachim Schaelerus reports that in that very serious plague in Britain,[244] birds were commonly found dead below the trees, with pustules under their wings. And so, at times when the drier and more independent[245] sort of animal is smitten by this disease, human beings suffer as well, and much more; it also appears to make its way across into horses.

Further, in an oak tree fruit called a "gall" which is occasionally not holed by March, there is formed sometimes a worm, sometimes a spider, and sometimes a fly. When a worm is formed, it presages plague; the worm arises from much moisture ill concocted. If a fly is formed, it presages fertility; it heralds thin moistness, well concocted; hence its message is of air at temperate heat, which brings fruitfulness. But if a spider breaks out, this indicates sterility; the spider is a cold dry creature, and this is why it contrives webs; cold and dryness are contrary to all generation and life.

To continue: the signs of fertility and sterility should be classed among four kinds overall. First, among the stars—but these have been clearly mentioned in their own places. Among the elements all excess is to be noted, such as excess of heat or cold or dry or moist; and excessive calmness and abnormality[246] of the air, such as a warm winter, a dry calm spring, a temperate summer. &1008 Among the plants phenomena like crop seeds being light or corrupt warn of sterility to come in that kind—and if this occurs at the Dog Star's rise,[247] they dry up fast. If this misfortune is severe, it runs into several years, as did the famine of Joseph under Pharaoh, which lasted seven years.[248] This is why sowers choose the better

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[242] "blattarum"—can also mean "moths."

[243] "affectus."

[244] This is probably the "English sweating fever," first recorded there in 1485 and subsequently reaching Europe; the final outbreak was in England in 1551. See Jean Fernel, *On the Hidden Causes of Things*, trans. Forrester and Henry, 593 and n. 180.

[245] "liberius."

[246] "perversitas."

[247] Midsummer.

[248] See Genesis 41: 53–57.

seed from this kind. Similarly with fruits, in which it is almost a permanent feature that the utmost sterility follows the utmost productiveness, whether this is through exhaustion of the trees' powers, or damage somehow to the buds[249] from which the shoots come, as occurs too from hail. From accidents and signs: earthquakes and locusts have quite often been the manifest and effective causes of sterility. Fish are produced by copious moistness, and wheat from a moist temperament—this is why it does not thrive in [607]St Thomas Island, as we have said.[250] In contrary fashion, abundance of corn makes for few fish.

But if I aim to cover everything, I am never going to reach a conclusion; there was that painter, outstanding though he was, who used to be abused by Apelles[251] for inability to take his hand off the canvas,[252] particularly since there is nothing harder for anyone than to know the future— this is actually so obscure that it cannot bring credit unless with the aid of some divine inspiration.[253] This is why those who excelled in it were not many, and deserved their title of "divine." Prominent among the men were Musaeus[254] the Athenian, and from the same town Lycus son of Pandion,[255] and Bacchides the &1009 Boeotian,[256] then Tiresias[257](another Boeotian), then the Cypriot Eucleus, and the celebrated Epimenides[258] of Crete. Similar among the women were the Sibyls,[259] so called

[249] In the text here of 1554 and 1560 appears "laesis germinibus à quibus germina prodeunt," which is an untranslatable surplus of "germina" unless the word is translated in two different ways.

[250] In Book VIII at 563 (1560). The island is in the Virgin Islands.

[251] Apelles, an exceedingly famous Greek painter of the fourth century B.C., "said that 'in every respect [his rival] Protogenes was fully his equal, or perhaps his superior, except in this, that he himself knew when to take his hand off a picture'—a memorable lesson, which teaches us that over-carefulness may be productive of bad results" (Pliny, *Nat. Hist.* 35. 36).

[252] The remainder of this sentence first appears in 1554.

[253] Material to [D] on 1010 (1560) first appears in 1554.

[254] A mythical singer, mentioned especially by Plato (*Republic* 364e) with Orpheus, and a reputed source of oracles of the future.

[255] Lycus, son of an Athenian called Pandion, was the reputed first Lycian, Lycians being the inhabitants of Lycia in Asia Minor. See Herodotus, *Histories*, 1. 173.

[256] Not traced; there is an irrelevant play of Plautus of this name.

[257] Legendary blind seer from Thebes; various accounts of the origin of his blindness were current (*OCD*). See Brumble, *Myths*, 322-24.

[258] Religious teacher and worker of wonders mentioned by Plato as alive in Athens about 500 B.C. For details of the wonders etc. see *OCD*.

[259] For the numerous times and places at which in antiquity prophecy was reputedly carried out by women called Sibyls see *OCD*. Especially notable was the account in Vergil (*Aeneid* 6, 77–102) of a Sibyl at Cumae near Rome.

from "sibullian,"[260] which means to prophesy, or from "sious,"[261] meaning "of the gods," and "boule," a piece of counsel. The most distinguished ones of the ten were at Erythrea[262] and Cumae,[263] and were called Amalthaea or Demophile,[264] or Erophile; their oracles were especially valued by the Romans.

But divining the future is fourfold: either from unusual events, such as the case reported from Switzerland, when two lions were seen fighting together in the air, and one severed the other's head. And armed men, and lines of battle, as in the time of the Maccabees,[265] and before the destruction of Jerusalem,[266] in the sky continuously for forty days. It might not be absurd to attribute these phenomena to mists, for instance too the varied shapes of clouds. But this has been discussed elsewhere. Or to prophetic power, on which we spoke recently.[267] Or to some natural art, such as astrology, physiognomy,[268] metoposcopy,[269] chiromancy,[270] navigation, agriculture, medicine, the interpretation of dreams.[271] Or to prodigies and omens and auguries, and discredited skills, about which we spoke in the fourth book of *On Wisdom*.[272]

There are so many important paths to foretelling the future,[273] such varied and unreliable ones, that it would not be reputable to attend to them, nor safe to ignore them altogether; and with everyone protesting at will and accepting worse predictions than those they grumble about, there are few people to be found learned in this topic who do know what they ought to notice as &1010
genuine, and what they ought to ignore as false.[274] For all truth is divine, and

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260 Aristophanes, the Athenian author of comedies, uses this word σιβυλλιάω in his *Knights* (l. 61); no doubt it developed from Σίβυλλα, a Sibyl, rather than the other way round.

261 "Sios" was a Spartan form of the usual Greek word "theos," meaning "god."

262 On the coast of Asia Minor, opposite the island of Chios.

263 On Cumae, see n. to Book II at 210 (1560).

264 Normal names of Sibyls of Cumae.

265 "For nearly forty days apparitions were seen in the sky all over Jerusalem: galloping horsemen in golden armour, companies of spearmen standing to arms, swordsmen at the ready, and squadrons of cavalry in battle order . . ." (2 Maccabees 5: 1–3)

266 By the Roman general Titus, in A.D. 70.

267 Reference not traced.

268 Prediction of character or of the future by inspecting a person's external appearance, especially that of the face. See Porter, *Windows of the Soul*.

269 Prediction by inspecting the forehead. See n. to Book XII at 833 (1560).

270 Prediction by inspecting markings or lines on the hand.

271 On Cardano's approach to dreams, see Siraisi, *The Clock and the Mirror*, chap. 8: "The Medicine of Dreams."

272 This work *On Wisdom* was originally published in 1544 (Maclean, *De libris propriis*, M47).

273 "tot, tantáque futura praenoscendi argumenta."

274 I hope that the translation of this monstrously long sentence is comprehensible.

proceeds from the best. [D] In serious studies outstanding men are found in more abundance, and I have chosen twelve[275] of them, leaving to each his own judgment.[276]

Archimedes is the first[277]—not just on account of the works of his now published,[278] but on account of the pieces of engineering he used repeatedly to destroy the Roman forces, as Plutarch testifies. In his life of Marcus Marcellus[279] he describes marvellous inventions of Archimedes, and we mention others just as remarkable, on the evidence of Galen, not so much the first author on both subjects, as one beyond imitation.[280] Nor the man who disdained[281] Greeklings (Cicero usually uses this name for all this sort of person) praising his talent, and searching for his tomb amid the ruins and brambles[282] of the town of Syracuse.[283]

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[275] 1560 reads "decem," obviously erroneously, and 1554 reads "duodecim."

[276] In 1550 and 1554 the order differs from that in 1560. Ptolemy comes second, and Aristotle third. Euclid, Scotus, and Suisset rank as fourth, fifth, and sixth. Seventh is Apollonius, eighth Archytas, and ninth Mahomet son of Moses. Tenth is Al-Kindi, eleventh Heber, and twelfth Galen. Siraisi (*The Clock and the Mirror*, 119) points out that in the first editions, Ptolemy was in second place. In subsequent editions, Vitruvius was inserted in twelfth place, and Ptolemy was transferred into a possibly higher category altogether, teamed with Hippocrates and Plotinus (see at 1013 [1560] just below). This higher category corresponded to Cardano's concern with prognostication and prognosis.

[277] On this order of merit of mathematicians, see Høyrup, *In Measure, Number and Weight*, 213. On Archimedes, see Clagett, *Archimedes in the Middle Ages*.

[278] Various works of Archimedes had been published in an edition by Tartaglia in 1543, and another edition appeared from Basle in 1544.

[279] Marcus Claudius Marcellus, Roman general who finally took Syracuse in 211 B.C. in spite of the skill of Archimedes.

[280] Syntax obscure: "et nos alia non minora, ex Galeni testimonio, in utroque genere non tam primus auctor, quàm inimitabilis."

[281] Reading "dedignatus" with 1554, not the "dignatus" of 1560: see the quotation from Cicero in n. 283 below.

[282] "sentes."

[283] In Book 5 of his *Tusculanae Disputationes*, Cicero digresses in the midst of discoursing on the futility of the existence of Dionysius (brutal tyrant of Syracuse from 405 B.C. on, but did successfully defend the town against the Carthaginians) by recounting an interesting episode: "When I was quaestor in Sicily I managed to track down Archimedes' grave. The Syracusans knew nothing about it, and indeed denied that any such thing existed. But there it was, completely surrounded and hidden by bushes of brambles and thorns. I remembered having heard of some simple lines of verse which had been inscribed on his tomb, referring to a sphere and cylinder modelled in stone on top of the grave. And so I took a good look round all the numerous tombs that stand beside the Agrigentine Gate. Finally I noticed a little column, just visible above the scrub: it was surmounted by a sphere and a cylinder. I immediately said to the Syracusans, some of whose leading citizens were with me at the time, that I believed this was the very object I

Second comes Aristotle the Stagirite, tutor of Alexander the Great of Macedon, who did marvellous work on natural and divine things and on dialectic; he investigated the life, habits, and anatomy[284] of animals with wonderful flair.[285] On individual fields of study he wrote what met with approval, yet over the course of so many centuries no notable mistake could be found in his writings. On similar criteria, the third place goes to Euclid, to Scotus,[286] and to Ioannes Suisset (whom ordinary people call the Calculator),[287] and with equal expectation; but Euclid should get preference through seniority and usefulness. He has two outstanding strengths: the unshaken stability of the doctrines of the book of the *Elements*, and a perfection so complete that you could not rightly compare any other work to that one. It follows that the only people who can distinguish truth from falsehood in &1011 difficult problems are those who have Euclid for their friend. He was descended from Megara, and he wrote much else that still survives, of equal subtlety, but much less useful.

Next comes Ioannes Scotus: that[288] was his homeland, and his doctrine earned him an equal distinction everywhere as a subtle teacher. Ioannes Suisset (already mentioned) was an inhabitant of the same island,[289] with the sobriquet "Calculator"; all posterity has striven to solve one single problem[290] of his, which is contrary to experience about mutual action.[291] People say that when he was old, he wept at not understanding his discoveries when reading them. I think

had been looking for. Men were sent in with sickles to clear the site, and when a path to the monument had been opened we walked right up to it. And the verses were still visible, though approximately the second half of each line had been worn away." Translation available at http://www.mathpages.com/home/kmath343.htm accessed on 6 Jan. 2007.

[284] "structura."

[285] "sagacitas."

[286] John Duns Scotus (c. 1266–1308), a subtle Scottish theologian and philosopher, based chiefly in Paris, and of considerable influence even now in the Roman Catholic Church. See T. Williams, ed., *Cambridge Companion to Duns Scotus* (Cambridge: Cambridge University Press, 2003).

[287] Richard Suiseth or Swineshead, English mathematician and Cistercian friar in the 14th century, taught mathematics at Oxford. Mentioned by Robert Burton (*The Anatomy of Melancholy*, 43, 462) as a calculator of genius. He discovered that the sum from n=1 to n=infinity of the series $n/(2^n)$ is 2. See also M. Clagett, "Richard Swineshead and Late Medieval Physics," *Osiris* 9 (1950): 131–61.

[288] I.e. Scotland.

[289] I.e. Britain.

[290] "argumentum."

[291] The article on Swineshead in *Dictionary of Scientific Biography* (3: 184–213) discusses the uncertainties on the identification of Swineshead and whether several individuals should be included. Book VII of his *Liber Calculationum* is devoted to "Reaction", but it is not evident what Cardano has in mind here.

this makes it certain that, as I wrote in the book *De Animi Immortalitate*,[292] the Barbarians are not our inferiors in talent, since under a foggy sky and divided by a whole sphere,[293] Britain has sent forth two men of such distinguished talent.

The sixth place is owed to Apollonius of Perge,[294] who was almost of an age with Archimedes. He wrote eight notable books on the elements of Conics, but of these up till now only the first four have been published, so foully defiled by the translator[295] that you could not fairly even call them published.

Next to him, but much senior, should be placed Archytas of Tarentum,[296] so that an Italian too can take his seat among such distinguished men. Beside the flying pigeon of wood that he is said to have constructed, he found a genuine proof of how to place &1012 two lines in continued proportion between two other proposed lines, a proof that among ten other false ones Eutocius[297] handed down. After him comes Mahomet son of Moses, the Arab,[298] inventor (so to speak) of the art of algebra—through this invention he got a name from the name of the art. Ninth[299] is Alchindus, an Arab himself;[300] an example of his publications (which Averroes[301] remembered) is the surviving book on the basis of the six quantities, which we will hand on for printing, since there is nothing more gifted.[302]

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[292] *On the Immortality of the Soul.*

[293] "divisa toto orbe"—obscure.

[294] See n. 27 above.

[295] By Giovanni Baptista Memo; published at Bologna in 1537. Only the first four books survived in Greek; books V–VII survived in Arabic, and book VIII remains lost except indirectly.

[296] Cardano however wrote "Archites;" see n. 143 above.

[297] Eutocius of Ashkelon in Palestine (c. 480–540). For details see *DSB*.

[298] Mohammed ibn-Musa al-Khwarizmi (before 800 A.D. and died after 847), prolific author at Baghdad on algebra and arithmetic. See http://www.ms.uky.edu/~carl/ma330/project2/al-khwa21.html, accessed on 26 Feb. 2008.

[299] Reading "Nonus" for the "Nonne" of 1560.

[300] Al-Kindi (c. 801–c. 873), first major Islamic philosopher, born in what is now Iraq. He was one of the earliest Muslim students of ancient Greek philosophers, and one of the first translators of the works of Aristotle into Arabic. He wrote more than 270 works, on a wide range of topics including philosophy, medicine, mathematics, optics, and astrology. He was much influenced by Neoplatonism and medieval Aristotelianism.

[301] The most famous of the mediaeval Islamic philosophers, born in Córdoba, Southern Spain. He was a judge successively at Córdoba, Seville, and in Morocco, and wrote on jurisprudence and medicine. In 1182 he became court physician to Caliph Abu Yusuf, but in 1185 was banished. His *Commentaries on Aristotle* were his most important works..

[302] ". . . quem nos excudendum trademus, exhibet cum nihil sit ingeniosius." I have ignored "exhibet," being unable to fit it into the syntax. Although Al-Kindi wrote many works, such as *De Aspectibus*, *De radiis stellarum*, *De temporum mutationibus*, *On the body that bears colour naturally*, *On the cause of the blue colour of the sky*, a *Recension of Euclid's*

After him comes Heber the Spaniard,[303] for a very famous discovery: since Ptolemy searches with huge labour for a sixth out of the five quantities, this man with three in the same category looks for a fourth. And he altered much on the state of heaven for the better, so that you can readily grasp how the highest tides in cold weather are much less of a trouble to chilly natures.[304]

Eleventh in subtlety, but the most famous in the art[305] is Galen, with his *Methods*, *Pulses*, and dissections.[306] But so verbose, and so tedious in his zeal to contradict, that you could hardly stand anyone else; thereafter[307] great deterioration of the arts took place, which the men of our own time have tried to make good.

[608]Last of all comes Vitruvius,[308] and if he had written of his own discoveries, not those of others, he could have been classified with the first. Some achievements stand out in detail: for instance, in Archimedes the equality of the sphere with the cylinder is engraved on his tomb;[309] in Euclid the order, in Aristotle the logical coherence,[310] in Galen the basis for splitting up.[311] Others too have distinguished endowments,[312] even if not notable for their subtlety. Who would not admire the passions[313] in Homer, the &1013 solemnity[314] in Vergil,

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Optica, and *On the Burning Mirror*, it is not evident what book Cardano has in mind here.

303 Also known as "Geber," as "Gebar Hispanus" and as Jâbir ibn Aflah, he was a Spanish Islamic mathematician (ca. 1100–1160) who devised astronomical instruments, and was notably influential because his works acquired an early Latin translation. See R. P. Lorch, "The Astronomy of Jabir ibn Aflah," *Centaurus* 20 (1976): 11–34. Also http://www-history.mcs.st-andrews.ac.uk/history/Biographies/Jabir_ibn_Aflah.html

304 "multo minus aestus maximos frigoribus gelidis obesse ingeniis"—obscure.

305 Evidently of medicine.

306 Burton points out (*Anatomy of Melancholy*, "Democritus to the Reader," 63) that Scaliger (*Exercitatio,* 224) derides Cardano's assessment here and calls Galen a mere "skirt of Hippocrates" ("fimbriam Hippocratis").

307 "in reliquo."

308 See n. in Book XIII at 872 (1560).

309 The "Hat Box" theorem of Archimedes; see nn. 82 and 283 above.

310 "contextus."

311 In chap. 4 of a Galenic treatise *De historia philosophica* reckoned spurious by Kühn, there are perfunctory remarks on division, first of words into meaningful and not so, of a whole into parts, of genera into species, of distinctions into individual characteristics, and of these into accidents (K. 19: 237). Cardano might have seen this work; it was attached (as Greek) to works of Aristotle published by Aldus Manutius in 1495 (BL catalogue).

312 "dotes."

313 "affectus."

314 "gravitas."

the ability to rouse pity[315] and the copiousness[316] in Cicero, the high quality of the oratory and the effects linked to the meaning of the words[317] in Quintilian? It is not a single kind of subtlety in which authorities are distinguished, but a number of them. Aristotle is famed for his talent, which Theophrastus and Scotus[318] envied; Archimedes for his talent and his imagination. For imagination, like the Calculator's.[319] For understanding[320] with imagination, like Euclid's. For judgment, like that of the Algebraist.[321] For understanding along with experience, like Vitruvius, with whom Hero vied, a man of great distinction for his inventions, though they were of little use.[322] Most distinguished in Vitruvius is the way his clocks work—either through floats[323] and water, or in adjustment to the rising of the stars from the Zodiac,[324] or by means of an analemma[325] which is common to plane[326] and spherical apertures.[327] These men were all of outstanding talent. But those who surpassed human powers and are regarded as closer to some divinity are three: Ptolemy of Alexandria,[328] Hippocrates of Cos,[329] and Plotinus.[330] To the last[331] I owe my belief that I can understand many things; to

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315 "commiseratio."

316 "affluentia."

317 "orationis qualitatem tum schemata sensui verborum apposita."

318 See n. 286 above.

319 See n. 287 above.

320 "sensus."

321 See n. 298 above.

322 Hero of Alexandria was a mathematician and inventor who flourished about A.D. 62. He described for instance siphons, lamps, a water-organ, and pulley systems. See *Dictionary of Scientific Biography* 6: 314–18.

323 "tympana."

324 "in anaporicis ex signifero"; ἀναφορικά concern the risings of stars, and the "signifer" holds the Zodiacal signs or "signa."

325 "A diagram showing (for a particular latitude) how the length of the shadow of a dial pin varies with the time of year" (*OLD*). Ptolemy wrote a treatise of this name. Vitruvius refers to the analemma (9.1.1, 9.6.1, 9.7.7; Loeb 2: 213, 245, 253, and the Loeb ed. provides specimens of analemmas (2: Plate L).

326 Reading "planis" though 1550, 1554, and 1560 read "plantis."

327 The remainder of this paragraph along with the subsequent one first appear in 1560.

328 See n. to 185 (1560) in Book II.

329 See n. to 357 (1560) in Book V. On Cardano's engagement with Hippocrates, see Siraisi, *The Clock and the Mirror*, chap. 6, 118–45.

330 Philosopher (A.D. 205–269/70) for most of his career at Rome, seen by some subsequently as the most powerful philosophical mind between Aristotle and Aquinas or Descartes.

331 Plotinus.

the second[332] my knowledge of the Art;[333] I admire the first because I can barely understand him. I link the fame of these men, because if the legacies of the rest had perished, with the treatises I have in mind and the assistance on which these men rely, I do not see why I could not restore the details, even if I could not.[334] But I understand well enough that in my whole lifetime I could not create seven lines of the work of one of them.

But those who regard Galen as the equal of Hippocrates admit by that statement that they understand neither of them; Hippocrates is far more different from Galen than Galen is from any &1014 child. And so the person who does not yet understand one out of these three can suppose himself trained to acquire knowledge from the intellect of others, but does not suppose that he himself knows anything at all; the measure of human knowledge belongs to these three.[335]

How everyone can pick up the drift[336] of complete books and the way in which each art can be taught is something that I find no one has laid down more precisely than I, except for Galen alone, and if we had stuck to this in good time, it would have exempted us from numerous labours. This is the same basis on which I have been forced to change my works fairly often right up to now, works that started to please others sooner than they did me. But now a plan for writing those that are to be published exists just as satisfactory to myself as to others—or so I reckon. Right up till now I have had no one to help me compose my books except God; I wish no one had been more of an obstacle.[337]

And so when I had started a chain of thought so as to decide that there was a limit even to this business, an opportunity presented itself, not without divine favour, for understanding Galen's view on this. The view was as follows: if you wish to hand on completely and perfectly a doctrine on some subject—this is the duty of any writer—you will be able to achieve this conveniently if we have split up the subject dealt with into types,[338] and have distinguished them into other lesser types, till we have reached the limit. And this plan will need to be followed in the influences[339] that can be demonstrated in connection with these types.

[332] "illi"—Hippocrates.

[333] Of medicine.

[334] "Coniector hanc claritatem virorum, quòd reliquorum si periissent monumenta, propositis mihi tractationibus auxiliisque, quibus illi freti sunt, cur singula restituere non possem, et si non possem, non intelligo:"—syntax and meaning obscure. Text shown is that of 1560. In order to attempt translation, I have hesitantly altered "coniector" to "conecto" and guessed the meaning.

[335] The next three paragraphs first appear in 1554

[336] "ratio."

[337] "vtinam non magis impedimento quisquam fuisset"—sense obscure.

[338] "species."

[339] "affectus."

&1015 This is the first rule. There will be another, for us to show that both in the types of the issue discussed and in the influences, that there are not and cannot be included any more kinds of members within the issue discussed, and that the members described are all included within it. The start of this splitting up will need to be drawn from the purpose of the art, otherwise we will be wandering in uncertainty. This is the way in which Galen taught us the rules of best construction,[340] and from there, who were the most outstanding people in the transmission of each art.

But now that we have reached the expert practitioner,[341] let us pursue the techniques[342] which have grown so famous in our time that what I have written here is going to command little credence with posterity. But if anyone reckons that every age possesses its own marvels, the oldest age following upon so many floods, fires, prodigies of the Romans, oracles, and miracles too—there is no reason why posterity should be in doubt about the technical discoveries of our own time—nor we in doubt about what deserved admiration and was handed on by others who lived in an earlier age. There are new technical discoveries every day, and they are not embraced in any limit; in some cases, it is enough to know what it is you wish. Recently someone has come up with the idea of a sword equipped with a spear; when the sword is pointed in some direction, it is doubled, and by being reinforced with a hook it resembles an iron spear, whose tip is the actual sword.

Someone else made an iron hand with a beak, and when it was touched, it used to clutch a thief's hand as its hooks drew together; it was hidden among the money in a purse. Thus there is no limit to what can be invented, and it only needs judgment.[343] Our age is prolific of distinguished and very great inventions.

340 "optima constructio."
341 "artificem."
342 "artes."
343 "iudicium."

[609] &1016 Book XVII
On the Arts and Artefacts

Surely among the other inventions the one deserving most respect is the basis of the mariners' compass,[1] with which so many seas have been ploughed; and with it the safety of so many men, and such vast resources, and indeed the life of princes are entrusted to the ocean depths, to the waste of waters and the whirling of the winds— and to such a small container and little rod— indeed to a modest needle? And it would not suffice just to have believed this unless it also guides and instructs us— and a stone without the power of sensation outdoes so many wise men with their sight and hearing.

The next award could be granted to the invention of military artillery, if it did not seem invented more for the destruction of the human race than for usefulness— hence the inventor's name is accursed.

There follows that marvellous technique of printing books with type, second to none after the first in usefulness and value and subtlety— and even if it were allocated that first place, we would believe this was no mistake. The whole of antiquity contains nothing on an equal footing with these three. I leave out the rest of the wonderful inventions of the present age, the ones that are making an addition to the old techniques, rather than outdoing the abilities of our great-grandfathers. If I wanted to include these, a whole book would not suffice, but I will add some examples.

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[1] "nautica pyxis."

Arches in temples:[2] bells in churches;[3] stirrups on saddles;[4] springs[5] in clocks;[6] the &1017 picking out of white lines in glass;[7] shape and speed in stamping out gold coins;[8] a wheel on which many threads are spun simultaneously, suppressed deliberately at Venice so as to look after impoverished little women and their children.[9] Discoveries too that have been out of use for a long period of time,

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[2] Though the Romans used arches extensively, in temples they generally followed the Greek pattern of post-and-lintel, familiar from the Parthenon on the Acropolis of Athens, but the Pantheon at Rome with its enormous dome is an exception.

[3] Their use in churches spread through Western Europe between the 6th and 11th centuries A.D.

[4] Introduced to Europe via Asiatic invaders around 600 A.D., though not widely adopted till the ninth century. Previously, four horns protruding from the saddle enabled the rider to stay on his horse.

[5] "molae."

[6] The earliest spring-driven clock is in the Science Museum in London and is dated about 1450 A.D. For a spring-driven clock to keep good time, it was necessary to develop some device to even out the torque provided by the spring, so that this was equal when the clock had just been wound and when it again needed winding. "Spring-driven clocks appeared on the scene towards the beginning of the fifteenth century—about 150 years after the invention of the mechanical clock. The principle was an old one, but well-behaved springs were hard to make, and even then proved frustratingly short-lived" (Landes, *Revolution in Time*, 86).

[7] "Venetian metal [i.e. raw material for glass], being particularly ductile, was usually worked [i.e. brought to final form] thin. It was therefore not suitable for engraving by ealier methods. From about the middle of the sixteenth century, however, it was occasionally engraved by means of a diamond point, which leaves a whitish spidery line on the surface of the glass" (Singer et al., *History of Technology*, 3: 216).

[8] Roller presses for this task were first developed between A.D. 1450 and 1650; previously and in antiquity every coin was individually struck by hand, so that each one was unique.

[9] "In March 1570 a . . . widow requested a privilege for a machine that could be used either to spin . . . several kinds of materials . . . or to twist and double silk, flax and other similar stuff." But the Signoria was warned that if the device proved effective, "it would be to the detriment of the poor, because this machine would cause unemployment among the poor female spinners and other sorts of poor women who ply the aforementioned crafts, that is winding silk . . . thanks to which they earn their living" (L. Mola, *The Silk Industry of Renaissance Venice* [Baltimore: Johns Hopkins University Press, 2000], 198–99).

such as the structure of quinqueremes,[10] and the composition of chrysocoll.[11] And the structure of Thracian cuirasses,[12] of which Pausanias makes mention in his *Attica* as if it currently existed and was well known: "Since the Sauromatians have no iron, and have not taken care to buy it or get it by exchange, yet have plenty of horses, when the horses die they used to collect the hooves and cleanse them and cut them into armlets; then they stitch them with the tendons of horses or oxen into the shape of the scaly skin of a snake, so that for anyone who has not seen them, they recall the fruit of the green pine tree. And such cuirasses were in usefulness and in elegance in no way inferior to the Attic ones made of iron; whether struck by javelins at some distance or by swords at close quarters, they resist admirably." Pausanias says that one hung in the temple of Aesculapius at Athens in his own time.[13] If it was now restored to those and other uses, I would not reckon that the inventor was going to waste his effort.

The skills[14] that are especially embellished by subtlety are painting, sculpture, and casting;[15] if an eye is even slightly too high up, or a nostril too narrow, or a lip too slanting, whatever effort you have invested goes totally to waste. In sculpture the ancients were so outstanding (people trace this back to the Jews)[16] that at the time the hand knew more than nowadays the eye can &1018 identify.

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[10] See J. S. Morrison, *Greek and Roman Oared Warships* (Oxford: Oxbow, 1996), chap. 7, where the arrangements of the oarsmen and the oars in the Greek and Phoenician and subsequent types of this vessel (the "five") are discussed. There were never sets of five *oars* in the vessels thus named, one above another. Major changes in design attended the development of medieval and Renaissance galleys, so that no vessels of the quinquereme type were any longer in use. J.G. Landels (*Engineering in the Ancient World* [London: Chatto & Windus, 1978], 152–53) also supplies information on even larger ships.

[11] See n. to 213 (1560) in Book II; the word means "gold glue," and both borax and malachite are capable of use as solders. The following four sentences appear first in 1554.

[12] "thoraces."

[13] Pausanias, *Description of Greece*, 1. 21. 5–6.

[14] "artes."

[15] "plastice."

[16] This is a surprising statement, since the making of "any graven image, or any likeness of any thing that is in heaven above, or that is in the earth beneath, or that is in the water under the earth" is forbidden in the Old Testament (Exodus 20: 4, repeated at Deuteronomy 5: 8). Hence only scanty traces of Jewish sculptors are found in the Middle Ages and Renaissance (*Encyclopaedia Judaica*, 14: 1059). See also A.A. Donohue (*Xoana and the Origins of Greek Sculpture* [Atlanta: Scholars Press, 1988], 94–103 and 128–29) on the inflexible Jewish condemnation of images, especially those of gods. Ficino (1433–1499), the Renaissance Platonist, was similarly uneasy about images: "Images or figurate talismans were both cherished and feared, and hence nervously qualified, retracted, and fathered upon Plotinus. Ficino's warning just after describing the talismans—'We ought not rashly to allow even the shadow of idolatry'—glances at 'Thou shalt not make a graven image before the Lord' . . . Insofar as his images were suspect, then, it seems to

Of the specimens of this wonderful kind I have seen the two Carneoli,[17] with unknown figures of animals. In fact, subtlety is the unique mother of all decoration—and not of decoration alone, but also very often of stability;[18] for instance, in the case of walls, precise vertical structure makes the work very stable and permanent—and if it has departed a little from that, it remarkably quickly demolishes them.

The skills that are only aided, if not embellished by subtlety, are the following: military skill, magic,[19] chemistry,[20] and engineering,[21] which is included in architecture. Painting is not just aided, but also embellished; painting is in fact the most subtle and important of all the engineering skills. For whatever casting or sculpture attempts, painting fashions it more wonderfully, it adds shadows and colours, and links optics to itself,[22] with some new inventions being added; a painter needs to know everything, because he imitates everything.

The philosopher too is a painter, an architect, and a professional at dissection. The evidence is that notable imitation of the whole human body was initiated a number of years ago by Leonardo da Vinci of Florence,[23] and nearly

have been because they were seen as addressed to demons. This accurately represents the Church's position . . ." (Ficino, *Three Books on Life*, editors' Introduction, 60–61).

[17] There is linguistic confusion in English and other languages between the pink semiprecious stone or quartz referred to as "cornelian" or "carnelian," and "caro (gen. carnis)," a Latin word meaning "flesh," and a similar type of cherry. Cardano may here refer to figures on a carnelian stone, since "an opaque white surface is sometimes produced artificially on a red carnelian: this is said to be done by coating the stone with carbonate of soda and then placing it on a red-hot iron; or by using a mixture of potash, white lead and certain vegetable juices, and heating it on charcoal . Inscriptions and figures in white on red carnelian ('burnt carnelian') are well known from the East" (*Encyclopedia Britannica*, 1911 ed.).

[18] "firmitas."

[19] "magia."

[20] "chymistica."

[21] "machinatoria."

[22] On this see J. V. Field, *Invention of Infinity* (Oxford: Oxford University Press, 1997), 207: "By the middle of the sixteenth century it was regarded as normal for an artist to have sufficient mathematical skill to give an appearance of three-dimensionality to pictures, as and when this was required. Later in the century there were in fact some artists who specialised in going much further than this. They painted illusionistic pictures in which at least some elements were to be seen as part of the real architecture of the room."

[23] On Leonardo da Vinci (1452–1519), the Italian painter, sculptor, architect, musician, mechanician, engineer and natural philosopher, see for instance M. Kemp, *Leonardo da Vinci* (London: Dent, 1981).

completed; but the work stood in need of a practitioner and investigator of nature as great as Vesalius.[24]

Now to say something about the principles of the art and of casting: this feature common to both must be accepted at the outset, as applying also to engraving and sculpture, that it is harder to fashion both sides of a face than just one; it happens that the representing of a face is threefold: the middle, the whole, and the &1019 three-quarters.[25] The example is taken from the face, because human beings are harder to reproduce[26] than beasts, and beasts than plants, and plants than districts[27] and their parts. Of the parts of a human being and its types, the entire face is the hardest to represent—first of all, because as a rule the work is doubled; then in the execution[28] of the work, if the craftsman has taken refuge in the size, number, shape, colour, blemishes, wrinkles, hollows, and other features without number that lurk in an average figure,[29] the obvious truth shows up the [610]inferiority of the work.

So those who wish to fashion something should (so to speak) first conceive in their memory the shape seen by their mind, and then trace out distinctly a more subtle figure;[30] afterwards, in the presence of your subject, attend to the details so as to bring them to perfection—a symmetry lurks in each[31] of the parts, and if you have not conceived it mentally, and try to express it in reliance simply on the assistance of your eyes, you will have wasted your effort. And you will not fashion a half (for example a side), since no one looks at a person like that, but with his head bent a little between one position and another.[32]

Thus it comes about that for this reason the centre of a face is easier to reproduce than the whole; as I said, since the centre has more positions, it follows that its form exists in some breadth; in the utmost perfection of the representation, the whole would be located in, so to speak, a single point. It is much easier to achieve something that has a quantity than a thing devoid of division, and capable only of mental conception. There appear to be three sorts of &1020

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[24] On Vesalius see C.D. O'Malley, *Andreas Vesalius of Brussels, 1514–64* (Berkeley: University of California Press, 1969). 1550 includes at this point a detailed discussion of colour which in 1554 was displaced into Book IV at 314 (1560) onward. For details see Nenci, 402 n. 85.

[25] "sesquidimidiam." Between a side view and a full frontal view; the "eye and a half," as it was known in the 16th century (J. Pope-Hennessy, *Portraits in the Renaissance* [London: Phaidon, 1966], 30).

[26] Reading "finguntur" with 1554 not the "funguntur" of 1560.

[27] Presumably this refers to maps.

[28] "comparatio."

[29] "in unius medietatis figura."

[30] "typus."

[31] Reading "unaquaque" instead of the "unoquoque" of 1560, since "pars" is feminine.

[32] "neque dimidium velut latus quoddam finges: nemo enim sic inspicit hominem, sed paululum deflexo capite inter vtrunque situm."—syntax not clear.

representation: the first in surfaces, and it is called a painting; the second in bodies already made, by engraving and carving them; the third actually creates the bodies, and is called casting.[33] It is clear that painting is the hardest of all, and so the most important. Its parts are three: delineation, shade, and colour. Since it is obliged to represent bodies on a plane, it needs the help of shadowing and delineation, and so is harder than the other arts, which express the likenesses on the bodies themselves. A matt white colour shows up smaller things, just as a dark one shows up larger ones. Evidence comes from printed books, where their ink makes letters look smaller the more dilute it is. So anything we want to paint as very small, we paint in white, as in the painting of the celebrated Guillaume Du Choul,[34] prefect of the Allobrogian[35] mountains, at whose place we saw many original and distinguished works while we were in Lyons. He is a very learned and humane man. Among many marvels of nature, he shows this work of art: a winter depicted in a painting. In it a knight is displayed in the distance among mountains, so that he can hardly be seen at all, and he is painted in white, with artistic skill, so that he seems even smaller than could be visible, and yet he is visible — the white colour is very near to the light, so that no part of him, nor of the light itself, can pass unnoticed. Nothing is in fact seen without the general capability of sensation.[36] Colours assist deception in this way, and this is more of a staining than a painting; it often happens that we tint old timbers with dye, and they &1021 look new. I pass over this for the moment, since it is very easy, and varies according to the nature of each timber. It is assisted in shadows by the darkness, and at times by a contribution from the modelling. When these two are linked in the *Supper of the Blessed Saviour* (that is His common name among the inhabitants of Pavia), the effect was that nowhere could any better painted theatre of columns be regarded as real; besides the darkness of the situation, and the marvellous diligence of the painter, the real arch in the middle of the picture deceives the eyes so well that you would have to regard the whole as painted, or the whole as actually constructed.[37] This art has advanced to remarkable daring, so great that it has sought to represent thunder, human voices, mental

[33] See n. 15 above.

[34] Gulielmus Caulius, a sixteenth-century French antiquarian; he published *Discorso della religione antica de Romani insieme un'altro Discorso della castrametatione, & disciplina militare . . . di detti Romani* (original publication at Lyons, 1555–1556).

[35] The original Celtic tribe of Allobroges inhabited the district of the upper Rhone valley, and consequently the cities of Lyon, St-Etienne, and Grenoble, and the modern departement of Isère, and some of Switzerland lay in their area.

[36] "communibus sensilibus."

[37] The reference here must be to Leonardo da Vinci's painting of the *Last Supper*, in Milan, created in tempera and mixed media on plaster on a wall 460 × 880 cm, so that the central arch is real, and indeed the subsequent opening of a doorway has effaced the Saviour's feet.

experiences, the sequence of the seasons, and features that cannot be painted, and barely described. The sequence of seasons and places it sets up in such a way that the first come in front and larger, and look transitory, like shadows.[38]

Example: after a game of Robbers[39] has proceeded, it needs painting. You will clear the places which the robbers left at first, since the experienced quite agree that from the outset there was a robber there. You will paint in effective colours those that have only moved forward once, just like those that have not moved at all, and correspondingly as smaller those that have moved further; and those on the opposite side, correspondingly larger. But if a piece has moved on twice already, the closer he is, the larger you should paint him, by a little, but the aspect[40] of the first move is more dilute and (so to speak) shabby—the place that it now occupies finally will show an aspect complete with colours.

Suppose some robber has proceeded three times; in the first place you will make a shadowy mark, in the second a &1022 more effective one, in the third a perfect one. Take a measurement from the one that has changed its place more often; let it be the robber that has already changed its place five times; in the end the robber will be released, and be painted with effective colours, just as if it had never been moved. In the next place to the last one, the robber will be weary, and will need painting as if the picture was already aged. In third place the robber is already shabby, but can still look unimpaired, with the remains of its colours still there. In second place the robbers will have the appearance of shadow, without colour support, but still intact. In first place will be only traces of shadow, and parts of the aspect will have fallen out, as if mutilated, but in such a way that the robber's shape can be made out, and sometimes the minds can follow that it has been there some time. Thus the resemblance of the rest is to be taken from the final sequences, not the first ones. So when there is no great difference of position, it will be easy to use the help of distinctions of the parts to reproduce the sequence, so that those that have moved earlier are placed, so to speak, at the outer boundary.

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[38] D. Pearsall and E. Salter (*Landscapes and Seasons of the Medieval World* [London: Elek, 1973], chap. 15) describe much artistic activity in the medieval and early Renaissance period in paintings indicating sequences of the seasons, e.g. by calendar sections, but not in the way here mentioned, and indeed (138) in a celebrated fourteenth-century English Psalter which otherwise depicts months, "little attention is paid to evocative colours."

[39] "latrunculi," "Roman chess," played in classical times, and even, according to Pliny (*Nat. Hist.* 8. 215; Loeb 3: 151), by monkeys. Details at http://www.romanglassmakers.co.uk/games.htm, accessed on 27 Feb. 2008. And see R. C. Bell, *Board and Table Games from Many Civilisations* (New York: Dover, 1979). I have not picked up evidence of any famous painting showing a game of latrunculi. The description here seems more like a coded version indicating the whole progress of a game, perhaps.

[40] "figura."

Likewise, the look of the face displays the progress of human beings and animals. But if a long distance is at variance with the sequence[41] of time, most painters take away the impression of a sequence by removing not only size but also colour. So unlike them, we will not paint the first place with an image reproduced large because of the nearness, but far off with a small and shadowy one, by removing the sequence of time — but certainly we will paint a large one close to, but just like a shadow, so that it represents not what is so, but what was so; and far off a small one &1023 in proportion to the distance, and vanishing, but not so much as the first one, nor with a part that is (so to speak) transitory.[42]

A feat even more remarkable than this, and closer to a miracle, is to paint a face looking backward in any direction — something we have sometimes seen. But on this we have already said much previously,[43] so must move on to the principles of engraving and carving.

I say that it is carving when we make images that protrude, as in statues and coins, which reproduce the images of [611]princes. To engrave is when we scoop out, as in the case of seals and other items made from gems, which squeeze wax to reproduce images. It is a good deal more difficult than carving: carvers are doing what they can see; engravers see one thing while doing another—while they can see, they can do nothing; while they are doing anything, they cannot see. Likewise, while they are engraving they cannot mentally conceive what they are going to do, though carvers can; the cavity is unknown in both its nature and its use. And if you slip up a little while enlarging what is to protrude in the wax, with the cavity in the gem enlarged you will have created an error which cannot be corrected without upsetting the whole work.

But in sculpture and embossed work[44] it is easier at the start not to remove too much, but actually leave it, than it is not to fill something up by engraving;[45] then if you even remove far too much, it is easier and more convenient to re-establish the whole work when the work is bulging[46] than when it is hollowed out. During engraving, right side corresponds to left side and left to right, &1024 which is the hardest thing in this work, when we aim to engrave a whole likeness — while in sculpture, right stays right and left stays left. All these reasons make it much more difficult to engrave than to carve. A very hard task of an exceptional type is to engrave a whole face, and even more so to do it on a small gemstone. This is

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[41] "successio."

[42] The obscurity of this long sentence leads to difficulty in grasping exactly what is meant.

[43] Reference not traced in *De Subtilitate*.

[44] "opus toreumaticum."

[45] Unclear: "quàm caelando non implere."

[46] "exuberante."

why I have had my likenesses engraved on many gems — chrysolith,[47] hyacinth,[48] and others — half my face,[49] or certainly three-quarters, with my name and fore-name. Those who paint or engrave or carve or model three-quarters add part of the other eye. This way of facilitating a confused recognition of a human being is better than the way of reproducing only half the face; but it is as much inferior in elegance of representation as it excels in ease of recognition — in the middle of the face are birthmarks and wrinkles and lines too, and spots, and one can reproduce precisely anything from that side; in the three-quarter view this cannot be elegantly done, since it follows no visible appearance.[50] Pure casting[51] is the hardest of all except painting, and is not inferior to that if it is not assisted by carving; all the difficulty an engraver encounters is met by someone who casts,[52] and even more — he faces the arrangement of the material, and knowledge of the fire's temperature, and the risk of many — indeed innumerable — disasters. For it is from previously engraved figures that statues are made with liquid poured in. So how can someone who has engraved wrong get the casting right? Münster[53] records that in Worms[54] there are five columns of marvellous casting[55] work. &1025 I was prepared to add this, since if he is not deceived in writing "cast" instead of "sculptured," this is serious evidence of outstanding skill and credit for the craftsman. Indeed, the casting invention presents more or less equal and extreme difficulty in very small and very large works; yet much greater difficulty in the greatest ones than in the smallest.[56] But in medium-sized works much less, so that they can be called easy. We have seen quite a number of craftsmen who thought themselves outstanding, because they had satisfied themselves in statues of moderate size, which they thought huge, and they provided an example of their ignorance and of the precariousness[57] of their work when these statues were left incomplete. What do you suppose would happen if a subtle execution of the lines and details is added to a great work? — will not the work extend nearly beyond human powers and the instances of resourcefulness? And so my remembering these five columns is to the point, provided they are of casting work, not another sort, as I said.

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47 On the identification of chrysolith, see Book VII at 462 (1560).

48 See n. to Book II at 102 foot (1560).

49 A side view.

50 I do not understand why this is so.

51 "plastice."

52 "qui fingit" seems to have this specific meaning here.

53 On Münster see n. to Book VII at 468 (1560).

54 Latin form Vormacia, in Rheinhessen in Germany.

55 "plastice."

56 Highly indecisive expression here.

57 "discrimen."

In the case of very small works, less industry is needed, so long as quite fine-grained[58] material is available. Was there not once the skill to create very large columns, colossi[59] and other items of this kind? I recall reading at Lyons a book in Greek which explained that the Rhodians had built huge works by this technique. It is also reported that the four huge columns that support the pinnacle of the temple of Athenaeus at Lyons are of this sort. And certainly they are embossed.[60] Some people hold that there was a technique to start with iron foam[61] and very hard stones found in the bottom of rivers, then with fairly hard powdered marble and &1026 white of egg, and to shape columns and vessels by a casting procedure, and bury them for many years. I think it was part of the technique for them to be pounded for a long time, and be completely reduced to the finest powder. The things most precisely shaped by fire are gypsum and sulphur. There is also a white material[62] from paper mixed with water and handled without fire; the products are pretty but not valuable.

From lime and its stones, ground very finely, a kind of cement is made (our people call it stucco), which sets to the whiteness and hardness of marble. This material is of some value, through the technique of casting; people cast woods and hunts, and other items too, in such fine detail[63] that with colour added as well they fetch prices of many talents. Some people grind up the same stones with fresh ox blood. Tufa grows out from these so hard that each item made from ground-up slices of it does not differ from the native stone. All this we have seen.

But nothing is more extraordinary than when we pour gypsum over the dead, or even the living, and engrave it cold in such a way that with oil and gypsum poured over, or paper or sulphur, we shape a human being so well that the image differs from the man in no point except in colour, and that it does not breathe. Those who attend carefully to this business coagulate together beard scraped off and hair shaven off from the dead image, and then by adding colour make a living likeness. While temporarily in France, I saw this kind of thing had been done to the recently dead Francis I, King of France,[64] in the house of the the very distinguished Cardinal of Tournon. Technique could not create anything more like a human being than &1027 [wrongly numbered 1017] that likeness—and it

[58] "tenuis."

[59] Especially the Colossus of Rhodes, an enormous statue at the harbour mouth constructed in approximately 304 B.C., which stood for some 56 years, and was one of the traditional seven Wonders of the World.

[60] "crustatae."

[61] "Spuma ferri," possibly what we would call iron filings.

[62] "natura." Papier-mâché.

[63] "adeò tenuiter."

[64] He reigned from 1515 to 1547.

was not of someone hardly alive.[65] Further, the likeness had been carried in the funeral procession. A way has also been found of transferring from large likenesses to small ones in a short time. What way? Just that when taken out of the casing,[66] it[67] contracts at once while it dries. It can do this because it is moist and soft and of thin parts, and yet is drawn together while it dries. So the centre of a hot loaf returns again into paste while it is pounded. The designs are executed on this, and are dried, and then with gypsum poured over and dried, it changes gradually to a smaller shape. This [612]also occurs due to thin pieces of linen for removal from the likeness, and they immediately contract. And by means of malleable cones.[68] Particularly in the case of pictures and statues and figures moulded in relief,[69] the proportion of the appearance can[70] be preserved, if anyone wishes to view the fruit of his skill; some pictures need viewing from directly opposite,[71] others from the side, others from a higher point, and some from a distance; statues in light, from a dark point; all tiny things in darkness, from the light, in case they become exhausted.[72] Similarly, colours look more vivid in darkness—hence the practice of drawing a curtain in front of shops that sell clothing.

Though these are in themselves instances of great subtlety, most of the important techniques are almost unseen, both because of the still unknown properties of things and because they need a more subtle strategy for their discovery. Some of these techniques are concealed, such as the method of making tenacious glass, the discovery of treasuries, the discovery of how to impart a whistling sound to air, and of taking away from white lead,[73] and of mining useful things from anywhere, and of altering colours. The complete system for converting spoiled wine into vinegar, &1028 discovered in my time yet forgotten in my time, even though we have passed on many quite useful procedures above.[74] The procedure for identifying the special powers of things. The art of lengthening life, on which

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65 1560 reads here "Nec nix niui." and 1554, "nec uix niui." The meaning is unclear.

66 "typus"; this meaning is a guess.

67 The cast, evidently.

68 "Et per conos ductiles." The meaning is unclear. The remainder of this paragraph appears first in 1560.

69 "ectypa."

70 Reading "licet" for the "dicet" of 1560.

71 "è regione."

72 "fatiscant."

73 "ab albo plumbo auferendi"—some casting process, perhaps. On white lead (also called "cerussa"), see n. to Book V at 357 (1560).

74 It is unclear what this system may have been. The ancient Orleans system for vinegar manufacture required a single cask, and there does not seem to be evidence that it originated in Cardano's time (see C. A. Mitchell, *Vinegar: Its Manufacture and Examination* [London: Griffin, 1926], 100). The "quick" process, requiring two casks, was first published in 1670, but might have originated earlier. See Conner and Allgeier, "Vinegar: Its History and Development"; and Mitchell, *Vinegar: Its Manufacture and Examination.*

we have spoken earlier. Making a material to resist the power of fiery devices. The invention of flight, which was tried out recently by those two men and ended very badly. Da Vinci, on whom we spoke previously,[75] tried it, and failed;[76] he was an outstanding painter. Above all is the magic of Tiridates, which drew for him from Nero a huge gift of money and the kingdom of Armenia, while he was teaching how to do what cannot be done.[77]

But there are some inventions which lay hidden for long, like clocks without a rope.[78] Instead of a rope there are wheels, and on some of them springs[79] are placed, snail-shaped, with 26 cogs, or even more in some cases. These propel round a toothed axle which operates the whole device. In another invention, there is a wheel with 48 cogs arranged at the bottom, and meshed with another wheel, so that when it is rotated by the torsion[80] of the spring at the bottom, the other wheel meshed with the same number of cogs and rotated carries the whole device round with it.

An invention was made on a similar principle, in order that the Emperor's travelling chair could be arranged so that whatever the position in which it was set up, he could sit unmoved and comfortable while it was carried along. This was drawn along on the gimbal[81] principle. With axes up and down, front and back,

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[75] See n. 23 above.

[76] Leonardo da Vinci certainly drew devices to enable man to fly, and speculation on whether he succeeded is widespread on the Internet.

[77] This tale is in Pliny (*Nat. Hist.* 30. 14): "The magician Tyridates had come to him, had brought magicians with him, had initiated him into magical suppers, but still he [Nero] was unable to acquire this art from him, though he was giving him a kingdom. Thus he was convinced accordingly that the art was infamous, pointless and empty, yet embodying some shadows of the truth; but in those the arts of poisoning prevailed, not those of magic." It also intrigued Jean Fernel (*On the Hidden Causes of Things*, trans. Forrester and Henry, 657).

[78] Also mentioned in Book I of the present work, at 27 (1560). And see n. 6 above.

[79] "molae."

[80] "nixus."

[81] "armillarum ratione"; astronomical instruments used a system of hoops to permit tilting in any plane, or stabilisation. This system, as used nowadays to keep marine compasses and the like horizontal, is called "gimbals." It is from this passage that credit has been given to Cardano for the invention of the "universal joint" found for instance on the drive shafts linking the engine to the rear wheels of a rear-wheel-drive automobile. Cardano did not invent nor claim to have invented the "Cardan joint" (Eckman, *Jerome Cardan*, 77). What he describes is really the "gimbal ring" suspension well known for marine compasses. The introduction of rotary force into this arrangement was described by Robert Hooke (1675–1703; see S. Inwood, *The Man Who Knew Too Much* [London: Macmillan, 2002], 108, 183–84, 209). It was elegantly illustrated in 1893, and Eckman cites F. M. Feldhaus (*Die Technik der Vorzeit der geschichtlichen Zeit und der Naturvölker: ein Handbuch für Archäologen und Historiker, Museen und Sammler, Kunsthändler*

and right and left (no more can be assigned), the person in the chariot can be at rest all the time, whatever the way in which it is moved. Lamps have a similar feature, and the basis is clear from their pattern: even if they are &1029 whirled round while open, the oil does not pour out at all.[82]

Recently too someone restored that universal device of the world, once made by Gulielmus Zelandinus,[83] broken up and decaying in darkness through neglect, after I (born under a lucky star for reintroducing good arts in passing, just as much as through hard work) had brought it back to light. On this pattern he made another in the time of the Emperor Charles V, such that you could see in it both the movement of the seasons and the parts of the individual constellations, and could observe the very slow motion of the eighth sphere. You can also examine in it the diverse divisions of the sphere of constellations, which are called "houses," and the equal and unequal hours, and—what is more—those that minister to the degrees of the whole universe, so that the device represents the sphere of the universe.

I do not mention the advance and retreat of individual planets, latitudes and altitudes and other details beyond counting, so that overall the subject is not less in reputation than it is larger in reliability. It is said that Sabor[84] the King of the Persians built a device of this kind from glass, so huge that he could sit at its centre as if in the little sphere of earth, and that as he looked between his legs he could see the constellations and the rising and setting stars—and appear, mortal though he was, to be above all calendar[85] and expectation of mortality.

And certainly, what could there be greater or more divine to come to human notice, even to the notice of a King possessing the whole earthly sphere, than to appear in possession of heaven and the stars, God's dwelling, after possessing the earth and the oceans? Someone &1030 proclaiming this was received by Honoratus Ianius Valentinus, teacher of the famous ruler Philip of Spain,[86] and a man very humane and very learned in humane letters, with these words: "This

und Antiquare. Leipzig u. Berlin, Wilhelm Engelmann, 1914, columns 870 and 871) for the description of the joint and the denial of its attribution to Cardano.

[82] 1550 and 1554 include a sentence here on Ianellus Turrianus Cremonensis who made many inventions of this sort, or improved those of others. Then material to [A] on 1034 (1560) first appears in 1554, except for portions first appearing in 1560. See n. to Book I at 19 foot (1560) on Giovanni Torriani and other forms of the name.

[83] The first public mechanically-operated clock was built about 1335 by Guglielmo Zelandino for the chapel of San Gottardo in Milan, and was the first clock capable of striking the hour.

[84] "Sapor" (the more usual spelling) was the name of Sassanid kings of the Persian Empire; the most famous, Sapor I (reigned A.D. 241–272), made war on Rome and parts of Asia Minor, initially with great success. See *OCD*.

[85] 1554 and 1560 reads "fastum" but "fatum" may be more credible.

[86] Not traced; the principal mentor of Philip II of Spain was Don Juan de Zuñiga (see M. A. S. Hume, *Philip II* [London: Macmillan, 1897]).

device used once to be made from glass, as you correctly said, not from metal as it is now; the authority for this is Claudian,[87] apart too from that of Cicero." But I would like to repeat his verses, for the sake of some uncertain person:

> When Jove looked down and saw the heavens figured in a sphere of glass, he laughed and said to the other gods: "Has the power of mortal effort gone so far? Is my handiwork now mimicked in a fragile globe? An old man of Syracuse[88] has imitated on earth the laws of the heavens, the order of nature, and the ordinances of the gods. Some hidden influence within the sphere directs the various courses of the stars and actuates the lifelike mass with definite motions. A false Zodiac runs through a year of its own, and a toy moon waxes and wanes month by month. Now bold invention rejoices to make its own heaven revolve, and sets the stars in motion by human wit. Why should I take umbrage at harmless Salmoneus[89] and his mock thunder? Here the feeble hand of man has proved Nature's rival![90]

"I ask," he says, "how with spirit included this mass could rotate with such diverse motions as Claudian describes? Then why was it made of glass long ago, and now of metal?" I replied, "The reason why the device of the celestial sphere was once made of glass was that, since it was really modelling heaven, the less was enclosed in the greater; &1031 hence what was inside and the stars could not have been viewed unless they had all been made from transparent material. And so the present makers of these structures,[91] uneasy about the fragility of glass, are obliged to have an unnatural model of the device of the universe, by enclosing sphere in sphere, and since they are made of metal, they cannot be seen; but they make as many panels[92] as there are spheres, or at least a set of six, of the Sun merging its sphere in that of Venus, and they assemble them into a circle, so that

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[87] Claudian (Claudius Claudianus) was court poet to the Emperor Honorius at the end of the fourth century A.D.

[88] Archimedes.

[89] Traditionally (e.g. in Vergil, *Aeneid* 6. 585 onward) a king of Elis who pretended to be Zeus and armed himself with fake thunderbolts and lightning. Zeus then smote him with the genuine items. See *OCD*.

[90] Claudian, *Shorter Poems*, 51: "*Archimedes*"; Loeb 2: 278: "Iupiter in parvo cum cerneret aethera vitro / Risit, et ad superos talia dicta dedit: / Huccine mortalis progressa potentia curae? [Cardano's word is *curat* here . . .] / Iam meus in fragili luditur orbe labor? / Iura poli rerumque fidem legesque deorum / Ecce Syracusius transtulit arte senex. / Inclusus variis famulatur spiritus astris / Et vivum certis motibus urget opus. / Percurrit proprium mentitus Signifer annum, / Et simulata novo Cynthia mense redit, / Iamque suum volvens audax industria mundum / Gaudet et humana sidera mente regit. / Quid falso insontem tonitru Salmonea miror? / Aemula naturae parva reperta manus."

[91] "moles."

[92] "tabulas."

the presence of wheels, weights, springs, little trucks,[93] cogs, bells, rods, ropes, and other components[94] is unseen inside—[613]although our craftsman[95] has not included weights or ropes, but has built everything from iron and cogs with marvellous skill; and the wanderings can be viewed with no obstacle, protruding from the boards with circles.

This makes it clear that that ancient structure was much more distinguished than ours, and prettier, but ours is the longer-lasting. And if they had been made out of hard transparent material, like the crystal we mentioned earlier made with silver mixed into it, then a natural round shape would have been adopted, and a structure of the spheres by which one was enclosed in another, and a transparency and beauty combined with permanence.

And now you have the reason for glass: it was difficult, especially then, to make this transparent device unless from glass, especially since these devices were then much larger than those now made from metal. And from this it is evident that such devices were &1032 not driven by weights; these could hardly have been got inside, and if inside would not have possessed perpetual motion, and would have fouled the good looks of the work; if the outside spheres had been moved from one side alone, they would have imposed a serious force on the glass. Hence it was easier for Archimedes to drive it with "spiritus,"[96] particularly because he had added just one movement to the spheres, and was placing them all around the same centre, like Calippus and Eudoxus,[97] and was pushing along a little spherical earth in the middle with a manifold movement, I cannot tell by what tricks—Archimedes reckoned that the parts of a sphere behaved in a way that he clearly asserted in his little book *On Sand*.[98] This is the view

[93] "currus."

[94] "instrumentorum."

[95] Who is named as Ianellus in the 1554 edition. See n. 82 above

[96] This might have been steam or air. Cicero (*De re publica*, 1. 14. 21–22) reported that the Roman general who captured Syracuse in 212 B.C. removed a much-admired single device of Archimedes which accurately reproduced the motions of the sun, moon, and planets (see article on Archimedes in *DSB*). See also reference to Cicero's *De Natura deorum* in n. 101 below. The word "spiritus" is apt here; as Grafton points out (*Cardano's Cosmos*, 162): "*spiritus* was the super-glue of the Renaissance magician's cosmos, a subtle matter that pervaded the universe, providing a channel for communication between the celestial and the terrestrial worlds." Cf. n. above in Book IV at 268 (1560).

[97] On Calippus and Eudoxus, see nn. to Book III at 262 (1560).

[98] This is the *Psammites* or *Arenarius* or *Sand-reckoner* (in Archimedes, *Opera omnia*, ed. Heiberg, 2: 216–59), which is concerned with the number of sand grains that would occupy the volume of the universe, and says almost nothing about how the parts of a sphere behaved. In dealing with such "astronomical" numbers, both the Greek of Archimedes and the Latin (ed. Heiberg) have to contend laboriously with the lack of a symbol for zero, which only became available with the introduction of "Arabic" (more precisely, "Indian") numerals later.

Nicolaus Copernicus adopted in our own age.[99] But to be precise, it is not entirely accepted, since it is not certain whether Archimedes intended the spheres of the Moon to rotate with the elements themselves, as Copernicus did.

So for two reasons it is clear that Archimedes found it easier to make this structure from glass, and drive it by "spiritus" without any other force, than is done in our own times by people that follow the views of Ptolemy. But I hardly think it worth much astonishment that this machine could be driven by "spiritus," when we consider with what force those machines made in Germany send out small balls, although they do it simply by air pressure. Perhaps Claudian understood "spiritus" differently, as the power hidden in springs, about which we spoke at the start of this work.[100] With the links systematically concealed, or as we said not long ago, in reliance on the help of cogwheels, the machine could seem in motion of itself, and with some "spiritus." &1033 This should not be interpreted just in connection with the motion by which stars are carried from the East to the West, since Cicero said this: "But if this sphere which our servant Posidonius recently made, and whose individual rotations do the same for the Sun and the Moon and the five planets that goes on in heaven during individual days and nights, were carried to barbarians like the Scythians, who in that uncivilised world would doubt that this sphere was a rational construction? They are uncertain about the universe, from which all arises and is made, in case it might itself have been a chance creation, or the result of some necessity or of a plan or of the divine mind. And people think that Archimedes proved more useful in modelling the rotations of the sphere than nature was in creating them, especially since they are more perfect at many points than these more cunning models."[101] These words make it plain that not only Archimedes before Cicero, but Posidonius in Cicero's own age imitated all the starry movements with that machine or globe reproducing the sphere.

And so Claudian could fairly explain how to interpret the power contained in the links and force of springs, a concealed and (if not lost) likeness of a machine operating on its own and moving itself by its own "spiritus," not as being air instead of "spiritus," but as itself a soul.[102] Recently one of my friends found a technique for adding sparkle to spun[103] gold. He also found a method which

[99] Copernicus (1473–1543), the Polish founder of modern astronomy, pioneered (1542) the view that the earth moved, rotating round the Sun like the other planets. But he did not hold that Archimedes had anticipated this view, as Cardano appears here to suggest, and he attributed any anticipation instead to two Pythagoreans of antiquity [*DSB*].

[100] See Book I at 27 (1560).

[101] Cicero, *Natura deorum* 2. 88; Loeb, 207. The Loeb translation renders the Latin "sphaera" as "orrery."

[102] The remainder of this paragraph appears first in 1560.

[103] "ductus."

permitted gold intermixed with silk to be spun, with a durable product; previously the texture was readily broken up because of inhomogeneity.[104] For the first invention, since he had a few days free of work, he would make an annual request for &1034 fifty golden crowns—for the second, for two hundred. He used to say that if he were to make the business of polishing gold last a whole year, his profit would reach a thousand gold crowns. Thus in great matters small exertion can feed a man, and in small matters great exertion can—the examples are numberless.

[A] Also, there are instances of subtlety linked to the craftsman, not to the art[105]—like Homer's *Iliad* written on parchment, which was enclosed in a nutshell. An ivory ship, which a small bee concealed with his wings. The statue of Memnon came close to being a miracle, the one that used to emit a loud sound whenever it was illuminated by the rising Sun. And this is no fabulous tale, which the serious authority Cornelius Tacitus[106] recalled, and Strabo recounts that he heard it:[107] it was at Thebes in Egypt, where there is a place called Syringa overlooking the Nile. Only the lower half of the statue survived, because Cambyses King of Persia had carried off the upper half as far as the navel—yet such a small part still produced the sound. Pausanias, who saw it and heard the sound, says it was very like lyre strings when they are breaking. There was in the past a chariot made by Myrmecides which a fly could cover; and ants made by Callicratides[108] out of ivory, whose parts could not be made out by other eyes. In Egypt, Ioannes Leo[109] records a chain made for a flea. You are astounded?—it was made in Germany, and exported to Milan. The extraordinary flea to which the chain was attached used to feed while secured by a hair. Do these feats display folly rather

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[104] "inaequalitas."

[105] "Sunt etiam subtilitatis propriae artifici, non arti, exempla"—the meaning may be that Homer's was the art, but the parchment manipulator was the worker in fine practical detail.

[106] Tacitus, *Annals* 2. 61: "the stone image of Memnon, which, when struck by the sun's rays, gives out the sound of a human voice"; as Cardano says, it was near Thebes in Egypt.

[107] "illum," evidently the sound, not (the voice of) Tacitus, nor the tale ("fabula," feminine). I have not traced any passage in Strabo's *Geography* referring to this. But Pausanias (*Description of Greece*, 1. 42. 3) wrote, "In Egyptian Thebes, on crossing the Nile to the so called Pipes, I saw a statue, still sitting, which gave out a sound. The many call it Memnon, who they say from Aethiopia overran Egypt and as far as Susa . . . This statue was broken in two by Cambyses, and at the present day from head to middle it is thrown down; but the rest is seated, and every day at the rising of the sun it makes a noise, and the sound one could best liken to that of a harp or lyre when a string has been broken." The remainder of this sentence, with the subsequent two, appears first in 1554.

[108] Two famous carvers of miniatures reported by Pliny (*Nat. Hist.* 7. 34, 36. 12).

[109] Leo Africanus; see n. to Book II at 161 (1560). The remainder of this sentence, with the subsequent three, appear first in 1554.

than luxury or subtlety? In our own age too, cages are made of box wood, the size of a hazelnut, with a perfect bird inside — and what is more remarkable, made inside &1035 seven hours. And in our own time, the following occurred to the Prince of Urbino: he was presented with a ring which was placed on his index finger, and had a gem on which was a perfect clock, which besides a line indicating the hours, would warn its wearer by a single stroke at the individual intervals of hours. These are marvellous works of subtlety, and cannot be permanent or useful, since they are obstructed[110] at individual moments; but they do simply produce astonishment, and so are good for the craftsman rather than the purchaser; their very slenderness serves as evidence of some special heavenly nature, and displays a [614]mixing throughout even tiny individual parts,[111] so that something dependent on skill linked to thinness is totally useless. Indeed, being able to separate in each case what is most slender, and knowing how to do this, is a task for some divine skill.[112] In this field the Indians excel; they use the smaller feathers of parrots and of some little birds to make likenesses so true to life that they yield to painting neither in fidelity[113] nor in charm nor in subtlety — and they even outdo it in brightness. A long task, and one for plaiting and finishing with reeds, not with fingers.

Skills are found that are outstanding in subtlety, while not divine: among these there are four[114] rather distinguished in the whole field: Magic, the study of the Signs of Concealment,[115] and Chemistry. Let us also add some illustrations of these. The study of the Signs occurs, for instance, when someone approaches you. There are signs of the intimate cast of the mind:[116] words, eye movements, the circumstances,[117] the place, the time, the customary behaviour of the mind, the &1036 condition of the body, the outward appearance,[118] the company, your personal knowledge,[119] the potentiality, the opportunity he grasps. If you weigh this up aright, you will readily appreciate what is in the mind of your visitor. At times it will be in order to guess from just three features: an enemy approaches you with quick step and fixed gaze — if he is an old man and unarmed, get your

110 "praeimpediantur."

111 In a real mixture, the characteristics of the components are no longer in evidence; as Book V at 350 (1560) puts it, "In the case of things that are really mixed, all the forms have to pass away, at any rate in part." Thus what we would call homogeneity is produced. It is possible that here a melding of heavenly and terrestrial nature is intended

112 The remainder of this paragraph first appears in 1560.

113 "repraesentatione."

114 But only three are specified.

115 "Notarum Occultandi."

116 "intimorum animi affectuum."

117 "causa."

118 "species."

119 "conscientia."

tongue ready; if he is a young man and armed, get your hand ready. By this little manoeuvre you can save your life and your reputation. Now there is no need to go into details.

But I move on to the basis of concealment. This is threefold: the basis of substitution,[120] which was in use, as Suetonius[121] long ago wrote about Caesar, as if D is written instead of A, and N instead of B. It is of innumerable kinds. The second is by "translation," which is twofold. The first is when, for instance, we write everything with three letters, with an aspirate easily added, so that no variety at all but this is present.[122]

Another method of "translation" exists, so that in some cases of suspicion, the marks may pass unnoticed; this is so with the Lacedaemonian cylinders,[123] and in others with nothing left behind at all, which is the most elegant method. You will receive two equal parchments marked out for writing, and on the actual lines little holes scattered from a position on both, but you will make them in proportion to the size or height of the elements. Some will contain seven, some three, some eight or ten elements, so that all the holes together contain 120 &1037 elements, with all those that can be written linked together.

You will give one of these parchments to the person to whom you wish to write. When necessary, you can write your first sentence very fast, in such a way that the sentence contains a smaller number of elements than that occupied by the intervals. Then you will write this sentence on a parchment placed under the holes, and again on another and another; finally, fill up the intervals of the first parchment by completing, deleting, and filling up the sentences, till the meaning is present. You will fill up the second sentence on the second parchment, in such a way that the words and the sentence appear to stick together. And

120 "transmutatio."

121 Suetonius, *Divus Julius*, 56: "if he had anything confidential to say, he wrote it in cipher, that is, by so changing the order of the letters of the alphabet that not a word could be made out. If anyone wishes to decipher these, and get at their meaning, he must substitute the fourth letter of the alphabet, namely D, for A, and so with the others." But it is unclear how Cardano reached the replacement of B by N, and there is no evidence of a misprint in the editions consulted. Such ciphers are still known as "Caesar ciphers."

122 An example follows, in which only a, b, and c appear, together with apostrophes, and no decoding is offered! In England, an improved technique was that of Francis Bacon (1561–1626) (details at http://www.bbc.co.uk/dna/h2g2/A9837183 accessed on 9 May 2007). He used a cipher in which the letters of the alphabet were represented by five-letter groups using only a and b, e.g. A=aaaaa, G=aabba, Q=abbbb. Rouse Ball (*Mathematical Recreations*, 397) points out that this plan provides $2^5 = 32$ possibilities, i.e. enough for the 26 letters of the normal alphabet plus 6 over.

123 "scytala"; or more usually, "scutula"; the writing to be encoded was written on a slip of papyrus wrapped round a scutula, see for instance Cicero, *Letters to Atticus*, 10. 10. Cicero uses the same word in Greek (σκυτάλη), and in his case no encoding took place, but the papyrus was formed into a scroll.

you will arrange in a third parchment that with the first letters untouched, the whole sentence, the number of words and their size are present, and retain their neatness.[124]

With this done, place on top the pattern you have cut out from parchment of the same size, and on the ends of the holes mark very tiny points as far as the letters you want to write extend. Then take the parchment and the letter in continuous words with a suitable pattern and size of spaces and of letters, like the first sentence—and let its words be held between the ends of the points. Thus no suspicion of a sham then remains; when your correspondent receives the sentence with the pattern placed over it, he follows the sense of your mind at once.

And though it is quite hard work, nothing can be found to match this for conveying one's mind to one's friends in dangerous times. To[125] make things easy, it is worth while having several panels[126] of this sort ready, of various sizes and distinguished by a different order.[127]

&1038 A third kind of concealment takes place when letters are written in alum; though hidden, they are legible when immersed in water, because the water darkens the parchment, and in it the alum glitters. Letters written in ammoniacal salt become visible when exposed to heat. Others are written in lemon juice or onion juice, and can all be read when exposed to a fire—otherwise they are invisible. But considerable effort is needed.[128]

The writing was done in the past on a quite thick and little-known kind of paper, of which my pupil Taddeo Duno showed me a piece; he is now a distinguished physician, and competent in many languages.[129] This piece had Greek letters written on it; and I noticed another feature on it, that of old, Greek books used to be written without accents and breathings.[130] An older age used to write

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[124] "concinnitas."

[125] This sentence first appears in 1560.

[126] "tabulas."

[127] This type of cipher became known as the "trellis" or "grille" and was attributed to Cardano. A late instance of its use in a Baltic State after the First World War is described by A. d'Agapeyeff (*Codes and Ciphers* [Oxford: Oxford University Press, 1949], 101–2). Rouse Ball (*Mathematical Recreations*, 392–93) points out that generating plausible "false text," the text which does not show through the orifices, is difficult and the security is poor, as d'Agapeyeff confirms. An improved technique described by Francis Bacon is mentioned in n. 122 above.

[128] 1550 alone includes two further sentences here on secret writing. The next three paragraphs appear first in 1554.

[129] Thadeus Dunus (1523–16130) was a former pupil of Cardano's who had moved to Zurich in Switzerland. Cardano was not always on amiable terms with him, and had differed from him over the treatment of pleurisy; see Siraisi, *The Clock and the Mirror*, 31–32, and *Biographisches Lexikon*, 2: 342.

[130] But this was long ago; the breathings were introduced by the Alexandrian grammarians, and the accents by Aristophanes of Byzantium in approximately 260 B.C., to

with tree bark[131] and wooden tablets. Even the books of Hippocrates were written on these, as Galen records. And writing used to be done with lead, and letters even in wax. What needed permanence was written in bronze. But Egyptian papyrus offered the greatest convenience. Apuleius[132] recalled this at the start of his book about the *Golden Ass*, saying: "Look at this only if you have not despised Egyptian paper written with a ready pen of Nile reeds.[133]

And there had been a vellum[134] made from kid skin, still in frequent use, more lasting than all the kinds of paper, and second only to bronze, which costs a great deal. A little before our own epoch, the works of the Fathers were mostly being written on "pergamene,"[135] since printing had not yet been invented, because something worth while would permit a more costly material. It was cheapened later with the invention of printing, since &1039 our paper, made from pieces of linen fabric long soaked in water, and pounded, and with the stuff[136] stretched out very thin over a brass mould,[137] so that the water can drain off, then put back between layers of woollen cloth till it dries, passes over into a marvellous whiteness, thinness, and lightness. After a further moistening with water in which gum arabic has been dissolved, it does not let the ink scatter about.

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facilitate the correct reading of Homer. The wheel has now come full circle, and since 1982 demotic modern Greek has been written without breathings and (apart from the acute accent) accents.

131 Medieval ink was of two quite different kinds. The first was carbon ink, made of charcoal or lamp-black mixed with a gum. The second was metal gall ink (usually iron gall), which was made by mixing tannic acid with ferrous sulphate and adding gum as a thickener, and became popular from the twelfth century on. Iron gall ink is made from "oak apples," ball-like growths found mainly on the leaves and twigs of oak trees. They are formed by the gall wasp. It lays its egg in a bud of the tree causing an apple-like ball, about the size of a marble, to form around the developing young. These balls were crushed and soaked in warm rainwater for several days to make ink. The second ingredient was ferrous sulphate, known also as copperas, green vitriol, or salmortis. When the copperas was added to the oak-gall water the resulting solution slowly turns from pale brown into black ink. Iron-gall ink undergoes a chemical change when exposed to air and light and darkens considerably on the pages of a manuscript. From http://www.history.uk.com/calligraphy/index.php?archive=4, accessed on 27 Feb. 2008. See S.J. Cornelison, "Pigments and Inks," *ODMA* 3: 1307-8.

132 For details of his life see *OCD*.

133 "argutia Nilotici calami inscriptam" (Apuleius, *Golden Ass*, 1. 1; Loeb 3).

134 "membrana."

135 A type of parchment. The word "parchment" is derived from "pergamena charta." Reputedly it originated at Pergamum, in the south of Asia Minor; see L. Casson, *Libraries in the Ancient World* (New Haven: Yale University Press, 2001), 52–53.

136 "puls"; "stuff" is now the customary term in the trade.

137 "cicotrigonizum"; not a word so far traced in dictionaries, but possibly related to "cicatrix," a scar. "Mould" is the present-day technical name of the sheet of metal mesh used for this purpose.

I recall seeing paper of this sort in which, before the invention of typography, volumes of the histories of Eutropius[138] had been [615]written (these belonged to my uncle Paolo Cardano, a man of great learning), which looked just as good as pergamene parchment.

But our epoch, too eager to amass gain, drags everything down, and this art of books—whether you consider the material, or the beauty, or the ease of production—seems to have reached a peak of perfection, so that you cannot long for anything more than it offers, even if you want to. And there is no art apart from this to which it seems impossible to add anything. As it was invented later than the others, the risk is that having come so quickly to manhood and maturity, it may slide again into neglect—which seems difficult even for excellent things.[139]

The art of chemistry possesses a number of admirable features, many pointless[140] ones, many more uncertain ones, no few pretty ones, some healthy ones, some others so effective as to seem divine, very many of no importance, others with great expectations, and finally, others more numerous than all the rest, and of major expense.[141] There are chemical discoveries: how to draw out glass into very long &1040 threads, how to manage it to become tenacious and very hard. It has certainly been long known that I have seen a thin sphere of glass which was harmed by no impact,[142] and was not shattered on a stone floor, but kept bouncing to the ceiling. Of this sort of glass there was some too that is marked out with white lines.[143]

But I think that smallness and roundness contribute a good deal to toughness,[144] because the air flows easily one way and another. I recently saw a chunk of glass up for sale instead of the gem aquamarine, for golden crowns—of wonderful beauty, enough to defeat the natural ones in brightness. It is part of the same skill, as I said, to stripe something with white lines, or engrave likenesses on it, to create fake gems, to cleanse camphor, to mix metals, to transmute them, or transmute more important things. Silk too is whitened like this by sulphur smoke; it dries too much, it stripes even flowers, particularly roses, for the same reason, for in a white part a diverse colour is restored.

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138 Eutropius was a historian of the fourth century A.D. who wrote a ten-volume history of Rome, "short, but well-balanced" (*OCD*), which was later translated into Greek and widely used.

139 "quod tamen etiam bellis difficile videtur"—obscure; I have translated on the assumption that "bellis" here is the dative case of "bellus" an adjective, and not of "bellum," the noun meaning "war."

140 "inania."

141 "iactura."

142 "conatus."

143 This impressed Cardano; see earlier reference at n. 7 above. This sentence and the next two first appear in 1554.

144 "durities."

This also explains how to make vessels for melting metals: they are made particularly from the tip of rams' horns, and from bones ground to dust, and powdered and crushed with a pestle. If you have added emery, or the fired tips of deer horn or of the jaws of a pike quenched twice or thrice in vinegar, the vessels will not break, nor will the metal escape; they are added from inside and all round, to stop absorption, but at the bottom especially.[145] The same source explains the use of distillation, its advantages, its powers, the vessels for it. But enough has been said above on its use, powers, and advantages; &1041 now let us discuss just the vessels and their kinds, in case this technique alone should seem inadequately conveyed. No doubt in this book all the techniques with which we are concerned are perfectly conveyed. But if I have not made this good, let me be universally distrusted, and rightly so; techniques are not conveyed here expansively, but under headings. And if I have not dealt with all the headings, I would be forgetting our plan drawn from Galen. If I have not dealt with the most salient headings, this book would not be about Subtlety. If then I have dealt with all the headings, both the very large and the very difficult ones, it is clear that anyone who follows what is written here possesses a perfect and complete acquaintance with the whole of technique. I explained the way in which we can approach an acquaintance with everything else by the resolving[146] method[147]—both from those that are close to the aim,[148] and from the aim itself.

But now I return to what I intend about the vessels, which I happen to have seen and handled, since my father paid the utmost attention to this technique, not following any method, but empirically. The vessels in which distillations take place are of four kinds: in fact [1] [*these numbers are inserted to denote the options*] either the distillation takes place in a single bell-shaped vessel, when the constituents that burn spontaneously are distilled with the bell turned upside down; what burns spontaneously, such as sulphur and pitch, does so, as was shown, because moist fattiness receives flames. But what is turned into smoke, on cooling condenses into moisture from the bottom of a glass bell; this is fatty, as was shown above. Then from the channel oil will pour out. [2] Or the distillation is carried out in two vessels. &1042 This goes on by two methods (omitting for now, as it is well known, the exhalation that occurs in the straight part of these vessels, especially when the matter inside dries up): either what is distilled returns into the same vessel, and it is called circulation, or into another, and this occurs in two ways, either in sloping vessels or in straight ones, of both of which I have stored specimens. [3] If three are required at the same time, one is called

[145] The following eight paragraphs, to [B] on 1050 (1560), first appear in 1554.

[146] "resolutoria"—presumably the Latin equivalent of the Greek "analytic" (ἀναλυτικός).

[147] See Book XVI, at 978 (1560).

[148] "finis."

Bozia by the barbarians; we will call it a reservoir.[149] A felt cap is placed on this, which is sometimes wider at its extreme top, and it has two openings: a shorter one by which it is placed on the reservoir, and the remaining wider one, by which the receiver,[150] the third vessel, is linked to it. And I have explained the shape of the oven serving several vessels, in which three points should be noticed: first, that the base should be perforated, where we do not want to completely receive a powerful fire; second, that it should have vents below for kindling the fire; third, that if we wish to distil with a slight fire, it should also have apertures above, by which the fire's force can be moderated. I have also copied the outline of a "Bain Marie," so that you can follow; it is usually made long, to accommodate a number of vessels. It should have a number of holes, so that the water can warm up evenly at the same time. It does not need to be tall, since the water boils with a small fire. And what is distilled on it needs temperate fires.

[4] The vessels are made from a number of materials: silver, bronze, pottery. But the best of all are made from iron, gold, and glass. From iron, when we want to apply large heat, as in oil of copperas.[151] Of gold, since our enquiry is into an issue involving our health, and its failure exacts a significant cost—for instance in dissolved gold, and ethereal water, and the so-called &1047 elixir. And from glass to process most other things; though glass makes no contribution, so gold does something for the perfection of such things. To prevent glass vessels from breaking, they should be thicker, and made of white glass, and be longer heated in the furnace, so as to be entirely free of bubbles,[152] and consequently of homogeneous substance and cleansed of all contamination. Also, it should be heated gradually, and cooled again. A soft base should be placed underneath, and if it [616]needs exposure to fierce fires, it is enclosed in mud and dung mixed, to the thickness of a finger, and very well dried. It is less fragile when it does not meet the heat by contact, but with a body inserted between.

Less costly items are generally distilled in brass and lead, for instance in a vessel with three orifices and comprising two components; the bottom can be separated from the rest, so that the sediment can be expelled. And it has an orifice above, through which material can be inserted, and on the side a long channel by which it is linked to the receiver. But in our own time, people usually place a leaden one with a channel on a brass vessel in the shape of a mixing bowl, and thus avoid having a second orifice; the material is inserted at the same place at which sediment is extracted.

Furthermore, I will now explain why there is such a manifold utilisation of vessels, omitting the bell we spoke about. When we want to distil something of quite thin substance, or to produce greater thinnness, very mild heat is required,

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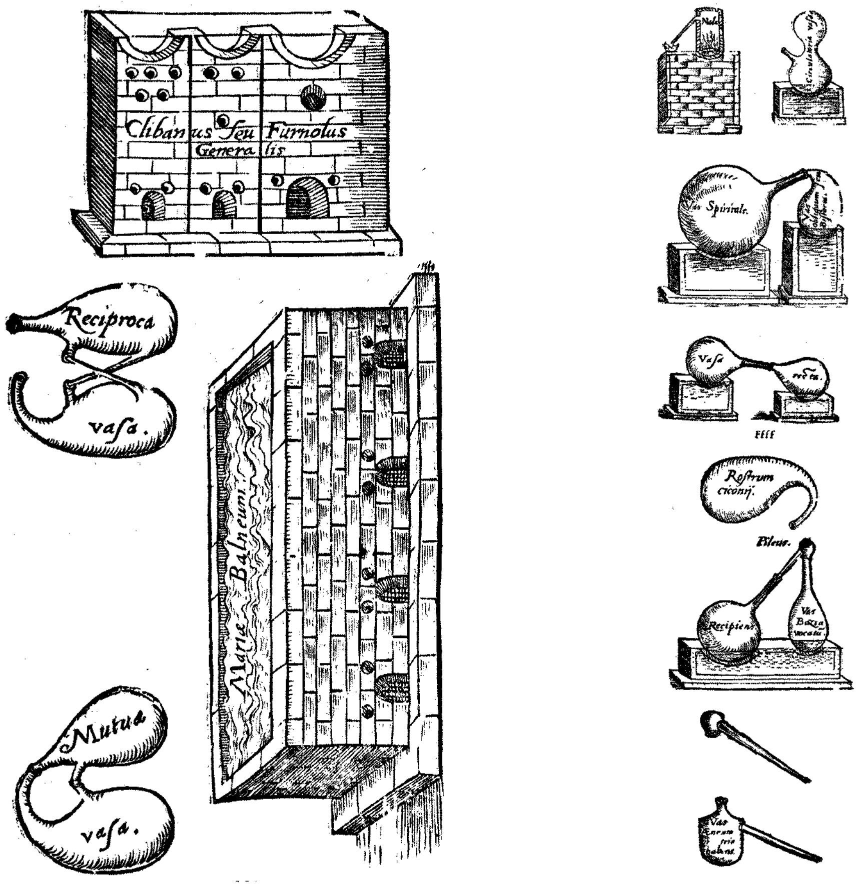
149 "conceptaculum."

150 "recipiens."

151 See n. on "calcanthum" in Book II at 131 (1560).

152 "ampullis"; normally means "flasks."



or the material is consumed. Mild heat is generated in four ways: either in the substance itself, when we distil in the sun or in dung, not on a fire; or in quantity, as when we use a moderate amount of fire. A smaller fire is made from &1048
willow wood than from holm-oak; or we put something between the fire and the vessel, such as ash or water. Water is best, because if spirit[153] is being distilled in a *bain marie*, there is the least breakdown of the best parts, and no evil odour is added; or if we distil at the top of the vessel, water is to be applied on a cloth quite often; it prevents breakdown and destruction by the fire. We therefore use circulation,[154] when we are concerned to expose this water to the nature of air, or when we have added a medicament and wish to impregnate the water with its powers. This method always needs a moderate heat, so that fire and a long delay

[153] "aqua ardens." 1560 amplifies the advice given here in 1554.
[154] "circulatio"; but the meaning of the word here is unclear.

are barely of use, so that for anyone correctly engaged in the business six months would hardly suffice.[155] So there is either simple alternation, as in circulating vessels, or mutual alternation, as in reciprocal vessels.

But even if it heats up a little with this multiple agitation, the substance's thinness exerts so little pressure[156] that it appears deprived of all heat; at each end the rest of the spirit[157] is safe. Either on account of the large supply of watery moistness mixed in during the initial distillation, or after numerous distillations and circulations, it then seems wholly devoid of heat, because of rarefaction.[158] And it is of such rarefied and thin substance that it lies on top of oil; what makes its way down is imperfect. [617]It is drawn down from every wine, but the best comes from what is best by nature and least spoilt. Half is usually drawn off in the first distillation, the same proportion in the second, little is lost in the third; almost nothing in the fourth, and much less in the subsequent ones, if you have carried them out aright.

This has &1049 many advantages, and is not to be neglected; it preserves some things, such as those that get corrupted, by performing the role of balsam; it alters some things for the better, such as human bodies languishing with cold; it cooks some things, such as eggs and flesh placed upon it. It picks up quickly the powers of all medicaments poured onto it, for instance those of the thinner ones in four hours, of others in eight, of harder ones in twelve, so that it almost never reaches a whole day. Then it is distilled again, with its powers retained, the sediment and all refuse removed. This is why alchemists usually call this sort of infusion the "fixing of stars in the sky." And indeed many people have been helped by its use. The usefulness extends from the eighth part of an ounce to a whole ounce. Hence it was properly for its sake that circulation was invented; what tinder[159] was used was mentioned previously.[160] Slanting vessels have been developed for the sake of the convenient position. Large ones to receive corrosive liquids, and in them copperas, saltpetre, alum and the like are distilled; when large fires are needed, making the smoke and the liquids made from it very corrosive, the receiving vessel needs to be very capacious, so that it does not break because of being thinned too much by fires with a content of air, and so that the driest and hottest smokes can be turned into liquid. Straight vessels are regularly made oblong and, so to speak, uniform, when a speedy transit is needed, and the vapour is rather heavy, as in the case of metals—or if we wish to collect over a

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155 The language is tortuous and the sense unclear.

156 "adeò parum imprimit."

157 "aqua ardens."

158 Syntax uncertain: "Aut in prima destillatione, ob copiam aquei humidi immistam, aut post multas destillationes circulationesue, ubi propter raritatem expers omnino caloris esse videtur."

159 "fomes."

160 Willow wood: see 1048 (1560) above.

gentle fire a corrosive water in which silver or gold has been dissolved with the metal left out.

The use of the felt cap is to absorb the impact of the vapour; hence even corrosive items are distilled in this way. The cap should be roomy in its top part. This is also done to avoid expense; the best ones are double-twisted,[161] are sold for more, and are hard to fit well enough for the vessels to be &1050 linked to their caps. We have already explained the benefit of a brass vessel, and that in the ovens there are apertures at the bottom, to fan the fires more vigorously. The top ones have a double use: to let out the smoke, and to calm the fire's power. And if you want to distil something light like very potent spirit[162] in the sun, you will put the centre of the container at the centre of a steel parabola; not only the point at the centre, but the whole vessel and anything lying within the boundary of the parabola boils and burns. Do not overlook that the steel should be polished.

[B] So much technical cunning exists that it can contribute distinctions between charcoals, over and above those we mentioned previously; it reckons those from the valley timber are better than those from the mountain timber; the valley timber is more loose-knit, and hence so is its charcoal, but an occasional fire readily ravages everything. However, in making charcoal it functions excellently, so that not just underground (as is the practice) but above it charcoal is made, because it burns better and is of more use. It is remarkable how much difference it makes how the fire is applied in the handling of metals, as well as of the residue created by the fire; the difference the fire makes is especially obvious in the case of gold leaf. So it matters a great deal whether you apply a continuous or an interrupted fire, a fierce or gentle one, a large or small one, gradually or abruptly, all round or from one side, stimulated by bellows or at rest, long-lasting or brief, in contact or outside the vessel, with a flame, or just embers, confined or free, simple or reflected, from charcoal or wood, or (what matters more) with other burning material added so as to retain its &1051 own power in the fire. It matters a great deal with what each item melted is associated; marble, galena,[163] lead, iron filings[164] combined with the stones in which metal is contained give marvellous assistance to their melting, and conserve their substance; while the melting is going on, they prevent the thin moistness contained in the stones from being used up, the opposite of the process mentioned above in relation to poisons. So with the stone heated up and not dried, and finally with the fire superheated because of its moisture content, it is necessary to melt the actual metal within the stone.

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161 "optimae enim bistortae carius veniunt, vixque tam benè aptantur."

162 "maximè ardentem aquam": i.e. exceptional "aqua ardens" (spirit).

163 A mixture of lead and silver ores found naturally, or the residue (chiefly lead) from the smelting of this (*OLD*).

164 See n. 61 above.

But why do metals not melt more easily when water or some other moist agent is added, rather than with more difficulty? Is it because water is cold and thin, and cannot melt because of its thinness, and because of its coldness cannot be properly heated until it is used up? This is also the way in which the crust that floats on a metal prevents it from melting; by solidifying so much that it chills all the parts, and thus obstructs their melting, or the crust removes the whole thinner metallic part—when it is gone, the metal does not dissolve. Similarly, when metals stick to the bottom, they do not melt, not even with powerful fires, since the heat makes for the top, but the little that stays at the bottom presently removes the moistness, and prevents melting; these are the two reasons why a metal at the bottom of the vessel does not melt.[165] We add a third reason: the insertion of water; it does not just hinder melting, but compels metals already melted to revert, with usually much harm to the bystanders. &1052 Some people have said that the thin moistness of water mingled with molten metals and converted into steam by the heat, since it occupies a greater space, forces the drops of molten metal to revert. But water, much lighter than metal, does not seem capable of entering its substance. It is better to believe that the metal's hot surface, already full of its own spirit, is contracted by the water's well-known cold, and as in the case of a ball that has been struck, it bounces back instantly from the ground with a great impact.

But the discoveries of this technique are a tiny part of those that could be made— such as the composition of electrum,[166] the softness of glass without firing, the genuine purple[167]—it is that in name only, and what was once discovered has already perished and ceased to be known: the composition of very beautiful and hard stones, and of very rarefied waters; it is possible with the former to make vessels, with the latter to extract gold and silver from sediments. There is far more one could write, but I have inserted these as examples. As a rule, the usefulness of something is [618]hidden along with itself; the use or necessity of

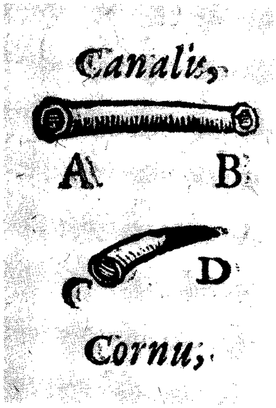
[165] The following paragraph first appears in 1554.

[166] This word can mean either amber or an alloy of gold and silver. The former seems much less credible here, since determining the composition of an alloy is a regular task for the metallurgist. And previously (see Book VI at 405 [1560], and notes there) the alloy is clearly meant.

[167] Pliny discusses purple at length (*Nat. Hist.* 9. 125–140; Loeb 3: 247–59). Variously known as Royal purple, Tyrian purple, purple of the ancients, this ancient dyestuff, mentioned in texts dating about 1600 B.C., was produced from the mucus of the hypobranchial gland of various species of marine molluscs, notably *Murex*. Although originating in the East Mediterranean town of Tyre (hence the name), man's first large-scale chemical industry spread throughout the world. With the decline of the Roman Empire, the use of the dye also declined, and large scale production ceased with the fall of Constantinople in 1453. It was replaced by other cheaper dyes like lichen purple and madder. From http://www.chriscooksey.demon.co.uk/tyrian/, accessed on 27 Feb. 2008.

military artillery and of the type for printing books did not come to light before the invention of the technique.

It is also a task of chemical technique to soften horn, which is done by prolonged boiling, with the addition especially of a moderate amount of ash or of lime into the water; this does not happen until the eighth hour. Out of this, handles and sword hilts are made, and combs, and chessmen.[168] Inkwells, boxes,[169] and other vessels, even if made in the same way. And there is another discovery of the French in this technique, and a far more distinguished one. In the cavity of a horn, as I have often seen, they fix a sharp iron, &1053 and then smear oil on the horn and hold it to the fire, turning it diligently; meantime they have a channel made of brass, a palm[170] longer than the horn, and at its bottom so tight as to be narrower than any horn, but a little wider at the start than an ox or buffalo horn can receive, perfectly straight, and they heat this with the narrower part in the fire and the other sticking out of it, for long enough till the wider part that



protrudes can be safely grasped by the hand. Then the horn CD is driven with a rounded wedge and mallet after being inserted by its thinner part (that is, D) into the brass channel, till D reaches almost to B. Then after a short break, before it has cooled down it is knocked out with wood and the mallet from the part B of the channel, and thrust again at the opposite wider part (C) with the same wedge and mallet, till it is seen not to move down further with the blow. Then the channel with the horn is immersed in water and cooled down and hardened there; after some hours a horn straight and solid and smooth on both sides is extracted. It cannot be bent later on without heating; hence it is best to use staining without a fire. The vessel AB is made of quite good Cyprian brass, and needs to be very smooth inside, and be turned round diligently while it heats[171] on the fire and over charcoal. It is clear that it is desirable to have many such vessels, and a table with holes in which the horn can stick firmly while being inserted.

Out of horns changed into a straight shape and solid substance &1054 by this technique, inkwells and other vessels are regularly made that are both attractive and useful. And it is obvious that cold or gently warm horn is blackened by vinegar and spirit and copperas. There are also some available that keep the substance of their colour.

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[168] For "Roman chess," "latrunculi"; see 1021 (1560) above.

[169] "thecae." The remainder of this paragraph first appears in 1554.

[170] See n. 268 below.

[171] Reading "calescit" with 1554, not the "stalescit" of 1560.

It is said that in a similar fashion even bones can be softened by juice of celery, yarrow,[172] radish, leek with vinegar, if they are immersed in this and covered over with horse dung.

But let us move over from this to evidence of the subtlety of various techniques. I wish to take five from architecture. First, the fortifying of towns. This is agreed to comprise a threefold technique: in barring invasion, repelling invaders, and protecting the defenders—there is nothing to find except these. We bar invasion by three expedients: water, ditch, wall. The ditch makes approach for assault difficult, significantly because of the descent, but much more because of the ascent. This is why the bank on each side should be steep, but especially on the side close to the city or town; the width forty yards, deep, multiple—if you cut a threefold ditch, it is not only beyond capture, but creates despair in the struggling attackers. Let it have seven yards of gushing water, since what is springing up cannot be stopped up or removed by any technique. While it is present it drowns the assailants; those it does not drown get their feet slippery and are weighed down with water, so cannot climb up. And it prevents mines, so that they can hardly be excavated—walls are undermined by them. In addition, anything thrown in is dispersed and broken up, and it prevents &1055 fire thrown in from spreading to destroy the walls. Walls to have a thickness of 30 yards,[173] thin cement, with stone or brickwork, the outside alive, hard, and protruding a little into a rounded shape. Walls simple in individual arms (this kind of measurement is explained: with us they contain 20 bricks, average ones such as "crassilii"[174] 32. Its height 100 yards,[175] as two are under the ditch, 60 to the top of the ditch, 30 above, and it is propped up by a very thick rampart inside. This applies in towns; less is enough in cities, in which the protection lies with the soldiers; if they are there, the city will be rendered entirely beyond capture. Repulse consists in ramparts and towers every 200 feet, with a wall straight in the middle, but above tilted towards the city—this is the way in which it does not prevent the impacts[176] of the towers, and the fiery balls of the enemy are made ineffective. The top of the wall is a rounded portion, in case lumps dislodged by the artillery might kill the defenders. In the inside part is a passage through which the guards can pass in safety. The earth at the bottom is hollowed out, so that the thumps made by those digging mines resound, and the soldiers will walk round in safety.[177] The accepted principle of the arches is: the more rounded it is, the firmer, right to the shape of a complete circle. Thicker ones at the bottom,

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172 "milifolium."

173 "passus."

174 This unorthodox word may mean "thickish" (walls). This sentence appears first in 1554.

175 "Altitudo illius passus 100"—this dimension is difficult to interpret.

176 "ictus"; probably missiles fired by the defenders are referred to here.

177 The next six sentences first appear in 1554.

and more slender as they move higher to the top. The sides are made from wide and thinner bricks on both sides where they start to be hollowed out, so that the joint sticks better with the seams[178] close together.

The foundation protrudes, and if it rests against[179] the wall, the wall is cut away, so that it receives and supports the foundation of the arch, like a supporting breastwork.[180] The thickness of this wall should be &1056 one and a half times, in comparison. But still firmer and thicker should be what extends underneath. At each hundred paces a dung privy and a well, because the need for water makes the soldiers withdraw, and water can be projected against fires, and against the heads of the enemy, after being heated; it offers a thousand other benefits. Dung corrupts the air. Extra hidden routes from the walls to the inside of a city fend off numerous discomforts, and bring great benefit to the defending soldiers, and leave them no reason to withdraw. [619]Another four or five routes, concealed from everyone except the prince himself, should be terminated five miles or even further away in thick woods, woods that long custom prevents anyone cutting down. This does nicely for sending out messengers and bringing in supplies and garrisons. The walls of the houses of the city itself should be surrounded by another wall, as I said, and defended, and no house should protrude. When Buer[181] was captured recently, when the hut[182] of a house had fallen down from an artillery onslaught (it was protruding), the princes of the town who were gathered there to take counsel were slaughtered. And while the French were besieging our town,[183] Marcantonio Colonna[184] and Camillo da Trivulzio[185] perished through a similar event; the result was that first their powers were curbed, then broken too, and in the end the dominance was torn away completely from Insubria.[186] It is virtually necessary to use one's own forces, conveyed secretly outside a town, so as to send out scouts. One should not resort to this expedient at once,

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[178] "suturae"—these are evidently what would technically be termed the "keys" of the brickwork. As the arch begins to form above rectangular bricks in a vertical array, the required bricks may be wider across but not so deep.

[179] "insistat."

[180] "pluteus."

[181] "Bura"; perhaps now Buer, near Gelsenkirchen and Essen in the west of Germany. This siege may have been an episode in the German campaign of the Emperor Charles V in 1546, when he split the ranks of Germany's Protestant princes by winning over Maurice of Saxony and defeating others.

[182] "tugurium."

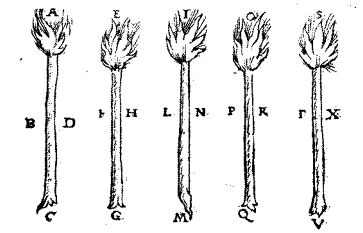
[183] Milan.

[184] Marcus Antonius Columna (1478–1522).

[185] Camillus Trivultius. Full details of the careers of both these military men are available in *Note biografiche di Capitani di Guerra e di Condottieri di Ventura operanti in Italia nel 1330–1550*, available on the Web: http://www.condottieridiventura.it/indicealfabetico/c.htm.

[186] North Italian district NW of Milan.

yet it should not be delayed so long that the struggle is lost, but done when the siege is vigorous and undecided.



Nocte postdiem Martis hora sexta nos hostem aggrediemur: vos exite cumomni milite, fortiterque pugnate: tota enim nostra

&1057 "During the night after Tuesday we will attack the enemy at the sixth hour; you are to move out with all the soldiery and fight boldly; all our safety hangs on this."[187]

And there is another solution to the problem of conveying plans to besieged towns, one that is safe and always available; and it is just as practicable to find out the intentions of those who are coming to the rescue, or will do so, as to reveal the town's condition, and it is not much different from a letter. So if the city itself wishes to signal its intention to a scout, or to the leader of the army coming to the rescue, &1058 individual burning torches should be placed on five towers placed at a distance from each other, so that they can be seen separately far away, and the individual people who hold them are to have in writing in front of them the words that they are going to signal; and as the letter comes up which belongs to his torch, or two or three letters, he is to signal it or them by raising or lowering his torch, or bending it to right or left. On a similar plan, by looking out from a very high tower, anyone can link up the letters and thus make out the plans of the leader coming to the rescue, even with the enemy army in between—with the enemy not noticing and indeed in ignorance, because the torches of the rescuers will be low down.

But I return to the fortification of the town: if it consists in high walls, this has a drawback in addition to the extreme building cost, because if the walls are demolished by artillery power, they will offer a very handy and safe bridge to the enemy. Lower, yet safer, ones against the ramps built by the besiegers do not make the houses or the soldiers safe.[188] Whatever must fall produces collapse before the crash is heard; since the framework is still supported, it has something to maintain it, and this has to be broken before collapse; while it is collapsing, the crash occurs. Hence for some people there is a single crash, for others several, in some cases it happens long before, in others at once. Also, cracks in walls when one part is gaping predict[189] a risk long beforehand. Some people say that the spiders take flight—nature was so anxious to appear wiser than human beings! But nothing is more sure than a tilt in the walls; even if no weight is pressing on them, they collapse of themselves. The towers are &1059 often built

[187] This sentence, italicised, appears in 1560 immediately below the adjoining figure of flowers. Evidently it refers to some stratagem for conveying commands secretly, a stratagem not further explained by Cardano here.

[188] The remainder of this paragraph first appears in 1554.

[189] "Praetendunt"; the meaning seems clearly to be "predict," though this is not classical (*OLD, L&S*).

for adornment, as in the past when Milan had three hundred; or sometimes for boastfulness, as at Pavia and Pisa; sometimes for protection, yet adornment is there too. Julius Caesar had once established a city at Strasbourg Inn[190] with 52 towers, and between each two adjoining towers there were seven raised parts of the parapet;[191] thus towers made up the weeks of the year, and the raised parts of the parapet the days of the week.[192] But as a general rule, as for many people who read this, or alternatively we may bring a reminder[193] of a well-known thing in a single word — in large buildings, one's own coaches for bringing and taking away contribute a significant help in reducing expense.

But let us move on to another example, more subtle but just as useful. Its author was Caius Julius Caesar, as he relates in the fourth book of his Gallic War.[194] He finished a bridge over the Rhine in ten days on the following plan, which we have undertaken to explain since few people understand it well.[195] Take pairs of timbers (marked in the diagram with the letter C), one and a half feet thick, and of such a length that when fixed in the bottom of the river they reach the surface, and link them with an interval of two feet on each side. Make them very sharp from the bottom up, insert them with machines,[196] strengthen them with straw, and fasten them leaning forward on one side with the river's current,[197] so that one of the timbers is nearer to the bank. Fasten the same number of timbers of the same size, similarly linked, and evenly spaced forty feet apart in the lower part of the river, leaning against its impact. Let these be called F. Link the upper joints C and F with a beam two &1061 feet wide, that is, in proportion to the size of the joint, with twin pins on each side tied from the inside part of the timber; the pins were enclosed and tethered by the beams, and are set there on the basis that the more they are kept apart, the more tightly they confine the beam, because they press it from the opposite side. Build more equal to these and positioned directly on the other part of the river, in such a way that the beam D is parallel to the other beam, and [620]similarly linked. And he again established the middle ranks during the same work, so far as was required.

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[190] "Argentoratum Taberna" is Strasbourg, some 120 km north of Basle, on the Rhine.

[191] "pinnae."

[192] This cannot be the work of Julius Caesar, who died in 44 B.C., though he visited the place during his initial campaign in Gaul. The fortification of Argentoratum was started by Drusus ("Germanicus"; 38 B.C. — 10 A.D.; see *OCD*) as one of 50 forts around the Rhine, and there was major further development about 80 A.D.

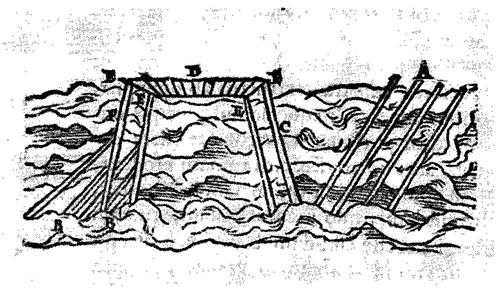
[193] "compendium."

[194] Caesar, *De bello Gallico*, 4. 17. 3.

[195] The details in 1550 and 1554 here are amplified in 1560.

[196] "machinationibus."

[197] "ad fluminis naturam."



Link these beams placed beside the flow of the river with many other transverse ones set on top of them and fastened to each other; the bridge is completed with long poles and iron grids on top. For its security, many timbers are placed in the upper part of the river, sloping towards the river's flow and separate from the whole of the work; in the lower part, stakes are also to be fastened against the river's impact, but much more tilted than the timbers, and firmly linked to the whole work. Thus the upper timbers will receive the river's impact and any scattered beams, and the more the mass is pressed by the waves, the firmer it gets through the shared interlacing. This is a stout bridge, and can meet any load. The speedy construction will only be revealed by the ropes and capstans,[198] or inflated hides, or linked timbers.[199]

More subtle, but less useful, is the plan for an amphitheatre which Pliny recalls. It is like this: when the son of Marcus Scaurus was going to give funeral games in his father's honour,[200] he could not equal the procession of Curtius,

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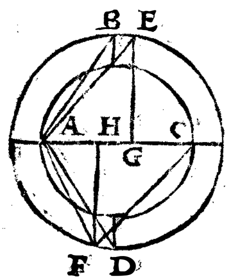
[198] "ergatae."

[199] In his *Dialogue on Waters and Fountains* (1557) Bernard Palissy wrote: "There are in many parts of France, and particularly at Nantes, wooden bridges where, to break the violence of the water and ice against the pillars of the bridges, great quantities of upright posts have been placed in front of the pillars, for otherwise they would not last long" (cited by C. J. Glacken, *Traces on the Rhodian Shore* [Berkeley: University of California Press, 1967], 470).

[200] Cardano's account is misleading here. Marcus Aemilius Scaurus (whose father's name was the same) was politically active at Rome ca. 65–53 B.C., and was inclined to spend his huge wealth on flamboyant games. The account (Pliny, *Nat. Hist.* 36. 116–120; Loeb 10: 91–95) reports that Gaius *Curio* (died in 49 B.C.; not the "Curtius" of Cardano) sought to emulate the ostentatious wealth of Scaurus without undue expense, and therefore it was he, not Scaurus, who created the twin amphitheatres here described, each poised on a pivot; in the forenoon they faced outwards and two plays were enacted simultaneously, the words in each not drowning those in the other. In the afternoon, the theatres rotated, some spectators even remaining in their seats, and "their corners met" ("cornibus in se coeuntibus"), to generate a circular amphitheatre in which gladiatorial contests could take place. Pliny is deeply impressed by the peril faced by the spectators in such precarious seating. And "when the pivots of the theatres were worn and displaced, he [Curio] altered this ostentatious display of his. He kept to the shape of the amphitheatre, and on the final day gave athletic displays on the two stages as they stood back to back across the middle of the arena. Then suddenly the platforms were swept away on either side, and during the same day he brought on those of his gladiators who had won their earlier contests."

because Curtius had given it with the utmost expense, being much more wealthy, and the son of Scaurus tried to outdo him in industry. &1062 And so he built two theatres of semicircular shape, with a stage, which when the stage show was given were to rotate on pivots and spread out an amphitheatre. While he produced the games in its orchestra,[201] and before the shows in the stages, the people that tamed the nations[202] were not only suspended on two pivots by a suspending device (a daring trick) but were even rotated. It is fair to ask, when the Latin stage is ninety degrees away from the highest point of the theatre and the whole diameter is 120 degrees, as Vitruvius explains,[203] what technique could allow both theatres to combine into one amphitheatre, without the stage being moved.[204]



Suppose there are two semicircles ABC and ADC, midpoints B and D. Let there be arcs AE and CF, the greater ones a ninety-third degree, and the lesser a ninety-sixth. Hence correctly[205] AE and CF will be greater than 87 and less than 89. So when pivots are placed at E and F, there will be GE and HF, the greater 59 2/3 and the lesser 59 11/12;[206] they are in fact less than half a diameter, because the pivots are away from the points B and D, which are the middle of semicircles, and that distance, as is supposed, is greater than three degrees and less than six. So AE and CF will project beyond the straight line AC, that is, beyond a semidiameter by more than twenty-seven 1/12 degrees and less than twenty-nine 1/3.

But the stage &1063 projects by thirty degrees beyond the semidiameter, because it is ninety degrees away from the points B and D, so when A and C rotate, they will not touch the stage. But they will not block each other either, because AE and AF are less than 169 2/3 in 1/60 parts, but AB and AD are greater than 169 2/3 in 1/26.[207] For AB and AD squared joined are equal to the squares of AF and AE, because they are equal to the square of the whole

[201] The part in front of the stage.

[202] The Roman audience—a grandiose phrase indeed.

[203] Vitruvius (5. 6) describes the geometry of the Roman theatre, in terms of a semicircle of seating divided into six bays; and a (much smaller and facing) semicircle accommodating the stage.The Loeb ed. (1: plate G) displays the normal layout.

[204] "A geometrical impossibility," comments the Loeb translator (D. E. Eichholz, 93 n. a). Margarete Bieber (an authority on the Greek and Roman theatre; see Bibliography) does not address it.

[205] Or "the straight lines," reading "rectae" instead of "rectè."

[206] Expansion of 1550 and 1554 4 occurs here in 1560.

[207] The rest of this paragraph together with the followking one has been modified in 1560 from the versions in 1550 and 1554.

diameter. So since AB and AD are equal to each other,[208] and AE and AF are unequal, AB and AD will be when joined greater than AE and AF joined by 1/18 of one degree. So a situation is to be found in which theatres rotating will not block each other.[209]

So the rotation should be gradual and by turns, since as I have said, the difference by which they can be separated from each other will hardly exceed 1/18 of one degree.

There are also two other ways, but less elegant ones, by which theatres can be built on this basis; but in the one, the theatres take on the shape of an egg, and so are not round; in the remaining way, although the amphitheatre is divided in the middle, it is not done correctly, nor according to the diameter.

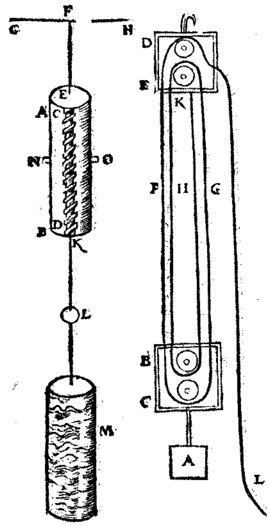
A fourth instance of subtlety is in pulley-blocks; it works out this way: weight A is connected to the lower pulley-block, in which there are two pulleys B and C, which rotate. In the upper block, there are two others, D and E; a rope &1064 is carried round D, and runs down through F to C, and ascends through G, and rotates to E, descending through H, it runs round B, and rising is bonded to the pulley-block at K. So the weight is pulled from L, and because it is held up by FGHK, it will only be a fourth part of the weight A, which is held up by individual ropes, so that it can be pulled by a fourth part of the strength. And if there were three pulleys in the individual pulley-blocks, it can be pulled by a sixth part; and so a child will be able to pull a huge weight upwards, provided there is no obstacle from the weight of the ropes, the roughness of the pulleys, and the difficulty of the motion. There is a ratio of the time taken, as there is of the power—through twin pulleys, the pull will be fourfold more slow; through a set of three, [621]sixfold more slow than if with the same power, or even a little more, it was pulled up with a single rope, and much more slowly, sixfold or fourfold, because of the amount the rope's length adds to the weight. The result is that that child will barely pull up a weight with these pulley-blocks over the course of an hour, that a six times stronger man, standing above with a single rope, can lift at once. And so it is a problem for technique and ingenuity to enable each person to lift any weight. But for a rope to be pulled by several people, it is pulled parallel to the earth under a pulley-block. And if one wants to pull more easily, we use a capstan, a tool in use by everyone; as its axles are driven round, the rope wound round it pulls any weights. But even with this, one can reduce the work as much as desired, by the length of the axles; they pull the more easily the longer they are.

&1066 Screws are made on a similar principle, and we call them "vines."[210] The screw AB, male inside, or the "vine" CD, which is rotated as usual; the

[208] "invicem."

[209] I cannot follow the argument and figures of this section.

[210] "vites"; this word provides the origin of the English word "vice," for a clamping tool.



handle EF, which is joined to the male screw, is turned on the axle GH easily, on the principle mentioned. At the bottom is KL, joined perpendicularly to the male screw, and to it is added a weight of (as might be expected) about 100,000 pounds, which is M. When GH turns, KL will be pulled upward, and the weight M will ascend; when GH is turned the other way, on the same principle KL will be pushed—and the iron facing it, of incredible thickness, will be bent.

So let us prove that the weight M can be moved, and on what principle: since M is 100 in weight resting on L, and since the individual threads support it, if there were ten of them, there will be ten thousand on each. But on each thread these ten thousand pounds hold back as much weight as is the ratio of roundness to the rope by which M is suspended. So the more threads there are in CD, and the lower they are (that is, closer to the circle, then the larger ones), the lighter the weight M gets, and the easier its movement—and the easier it is, the slower it gets. So the screw can have an interval of two cubits[211] with threads so wide and low that the weight M will be easily pulled up by a ten-year-old boy. However, as I said, the easier it moves, the slower it does so. So when it has been pulled close to LK, the length M will need to be suspended by the supports of the device at N and O. And then when the device has been sent out again by contrary motion, we add the weight to KL, and we will pull once more, and elevate by the interval KL, till by tying it quite frequently we draw out a ship from the sea or from a river, or some &1067 other huge weight.

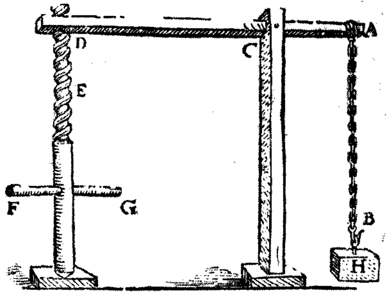
This should be regarded as the device of Archimedes, augmented by the lightness and antiquity of the Greeks,[212] by which he attracted the admiration of the ancients; in this way a child will easily drag a loaded ship, which not even twenty pairs of oxen could displace. It is made of the hardest steel, so as not to bend; of the lightest steel, so as not to be hindered; and solid, and lubricated with oil; oil is quite helpful to motion, because it is smooth. And as it is resistant to decay, it does not permit rusting. Of the agents that offer easy movement, olive oil is the main one, though more effective is the oil made from matter containing a slimy moistness, such as fenugreek. Josephus relates that someone fighting for the Iotapateni made a bridge sprinkled with an extract of fenugreek so slippery that the Roman soldiers abandoned the siege they had started, since they could

[211] See n. to 26 (1560) in Book I.

[212] "levitate Graecorum et vetustate"—sense unclear.

not maintain their footing;[213] and the smaller the expedient[214] is, even though it pulls with some difficulty, the more the astonishment it generates.

On[215] this principle a device has been invented for the lifting of huge weights, which consists of a screw tool and a capstan. Let AB be a chain, the weight to be lifted H, the beam to which the cross chain is attached be AD. On a timber C standing perpendicular, let there be a place in which a pin is fastened in the timber, on which the hollowed beam AD rests, so that A can move up and down, while D moves down. Let DE be another perpendicular timber, which is carved like a screw and is received by the beam at D; and let the capstan be FG. The part of the beam that represents a &1068 male screw is E, just as in the beam the female part of the screw is D. The timber DE is capable of rotation by the capstan, and DC is part of the beam and three times as long as the external part AC. As an example, FG is eight times the thickness of DE. Let the ratio of the screw's width to its depth be five times; we will then multiply this (from what was shown here and in the first book), eight by five, which makes forty, which multiplied by three gives 120.



So if H is a weight of 1200 pounds, since this divided by 120 gives 10, it will be lifted by a force capable of lifting 10 pounds, with the same effort with which those ten pounds are lifted. But if the hub[216] D stays still in the screw socket,[217] as is reasonable when the capstan is not moving, a rope or [622]chain applied to the weight to suspend it meantime from another timber fixed close to AB will enable H to be pulled up to any height you wish, when the beam AD is put back in place.

Münster[218] reports that in Alsace, the water is pumped &1069 out of the deepest wells through coach[219] wheels and containers made of oxhide,[220] with such force that although the wheels are made of wood and are wet, they strike

[213] Josephus, *Wars of the Jews*, 3, §276: During their defence of Jotapata, a town in Galilee to the north of Sepphoris, Jewish forces in A.D. 67 used fenugreek to make boards so slippery that the Roman forces lost their footing.

[214] "instrumentum"—oil, presumably. All of this sentence except this final part first appears in 1554.

[215] The next three paragraphs first appear in 1554.

[216] "modiolus."

[217] "in partibus cochleae."

[218] On Münster see n. to Book VII at 468 (1560).

[219] "bigalibus."

[220] "curribúsque è bubali corio"; "currus" means a "chariot" or even "a pair of wheels," and its meaning here is speculative.

fire. So this device is seen to embrace three notable features: height, capacity, and speed.

But setting this aside, let us move on to waggons and coaches. All those that are supported on rather large wheels travel very easily and fast on soft ground, because any adherent mud takes up a minimal part of the wheels, and so is barely obstructive. Always, too, a larger wheel covers the ground faster when it is adequate for carrying the load. And the fewer of them there are, the faster the trip is completed; if there are more, and they are small, with their smaller circumference they cover less ground;[221] if they are large, they add their weight to the force, but do not come in contact with more of the ground, and so move more sluggishly. This is why Roman Emperors used to be conveyed in an "essedum," that is, a chariot with two large wheels; when the weight is not so great, or is pulled by extra horses, the journey is completed very fast. This is why military artillery of excessive weight is moved in "esseda." Again, the reason for easy travel is exactly the opposite of this; on solid ground, more wheels outdo few wheels in ease of travel, and small wheels outdo large ones; the weight is, so to speak, shared out among the wheels, so that there is an addition of their contributions, not a multiplication. Example: doubles multiplied together six times give a ratio of 64 to one.[222] The same linked make twelvefold—there is such a difference between addition and multiplication. &1070 Consequently since on one wheel a weight contributes 60 pounds, and on six wheels, 10 pounds are equivalent, so assistance is derived from smallness, for the slower the travel, the easier it is. But the saying is that weights travel and are drawn along more slowly and on small wheels of iron than on large wheels, to the extent that they travel more easily.

There is a third reason for easy travel: because the axle is not under pressure, and so rotates more freely. This is why big weights on firm soil are set on their way in small and low wagons, which do not rest on axles with several wheels. But on wet mud a few large wheels convey loads not only much faster but also more easily. And since spokes running straight out from the axle let the wheel turn faster and more easily, when they protrude outside a little they carry the load better, and are easier to mend.[223] Those that have larger wheels at the back than at the front are easier to pull, as if the load were bearing down on them, since the load pushes itself onward, and on a rise they get equal, although in them the front parts are under more pressure than is right.

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[221] "spatium."

[222] "Sex duplae invicem ductae, sexaginta quatuor ad unum reddunt rationem." Two to the power six does give 64; elastic translation is needed to extract this correct result from the Latin.

[223] This sentence first appears in 1560.

We spoke[224] about the axles of capstans, because they ought to be quite long; the individual handles[225] reduce the weight in proportion to their length. Handles doubled in this way reduce it to half, and thus four reduce it to a quarter. This is so true that if on a single axle a cubit[226] long, four men can transport or pull along a hundred pounds, on four axles each six cubits long the same men will carry 240 pounds, but with deduction of the added weight of the axles, which is minimal. While we &1071 were discussing the steelyard[227] previously, this relation was proved. Thus it comes about that with people leaping up steps in the largest wheels, the largest weights are pulled by a rope wound round the axle.[228] As the ratio of the wheel's diameter is to the axle's diameter, so is that of the weight raised by the rope to the weight and strength of the men who move round within the wheel.

The theory of impacts is similar: an axe strikes with an impact, what is pressed by the greatest weight is not split, and yet the weight will have greater power than the impact. The reason is that the air cannot get out in the blow; though the edge is sharp, it[229] cannot get out in such a tiny moment. To prevent its getting too compacted, it is compelled to enter the pores of the wood underneath, and to split it like a wedge. The evidence is that a slightly slower blow introduces a very large difference in the dividing, as the air slips aside. But if the blow on a wide item is fast, as the air enters, what is below breaks up, apparently to nothing—as occurs with those struck by the missile of the machine called a bombard.[230] But a man can hardly move anything large very fast, even if it is very light; this is why whatever is struck must be broken up into air and spirit.

But why does a sword strike most at its end? Because the centre of motion is the hand; the circumference is in the tip, and so even armour and helmets are divided at that interval. Similarly, we are safer when close to kicking horses than when a little further away. Drawing power[231] adds a good deal to the force, since if what is divided is not drawn aside, it obstructs the division; during rapid drawing aside, what is obstructing &1072 is removed, and thus in a threefold fashion the blow combined with the drawing power cuts better at the end of the sword.

Also, spears of greater length do more damage, and pierce more than short ones do, because they are heavier and are projected with greater force, although

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[224] At 1064 (1560).

[225] "capita."

[226] On the cubit, see n. to 26 (1560) in Book I.

[227] See nn. to Book I at 57 and 60 (1560).

[228] This may refer to mounted wheels serving as treadmills, inside which men walked on steps to rotate the wheels.

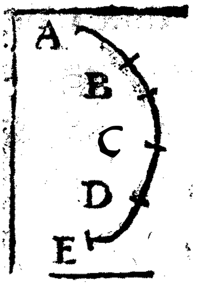
[229] The air.

[230] See n. to Book IV at 301 (1560).

[231] "Attractio."

the usual view deceives us.[232] Remembering this called the following to mind, and if it did not happen every day, it would be regarded as almost miraculous. A laden ship that forty yoke of oxen could hardly move—the wind propels it very fast—and what matters more, the sail is thin, and a finger could push through it. But while curved, it pulls such a large bulk, and does not burst. The reason for its easy movement is threefold: though the sail is large, it is held together by the wind,[233] and the height, as has been shown, and the impact of the previous motion; at the start it can barely be moved.

Hence Aristotle would have doubts—he thinks that violent movements diminish near their end. It is accepted that with unchanging wind, if the rest stays the same, a ship's motion keeps getting faster. Surely not forever, but up to a limit? It is obvious that from the start it increases. And there is a reason, since as we said, the violent motion itself increases even when what is doing the moving is stopping, and much more if the cause is still persisting. Still more so in water, because of the greater resistance.[234] Thus ships at full speed move faster than at



the beginning, in three ways: we have already shown the reason for [623]these, as I said. But how is it that such thin linen resists such a force that the actual masts and ropes break more easily than the sails? This is why: because the wind's &1073 force is split up among the parts of the sail. Let there be a sail ABCDE, and if all the force that drives the ship were gathered together in part A, and also since B is billowed out twice as much, and thrice as much, and up to the number of the parts, would it move faster? But it does not move, and so the whole force is not gathered in one part. So the force must be spread out according to the size of the sail's parts. And this gathering occurs on the basis of multiplication, not of addition; so by a small impact a large weight is moved in this way; if you link triple four, twelvefold is made; if you multiply, the ratio will be 81 to one.[235] So 30 are gathered by way of addition from six fivefold, and from five multiplied in doubles comes 32 in turn.[236] If they are compared together, five doubles will move a weight of six fivefolds. Hence large sails tear with more difficulty than small ones while evenly moving. And the ratio of the motion is not that of the sails; for a sail which occupies ten yards, if it propels a ship four miles per hour—one that occupies 15 yards will propel it faster, in the proportion of the excess of 15 to the magnitude by the agency of which the ship starts to move

[232] The remainder of this paragraph together with the two subsequent ones first appear in 1554,

[233] Reading "vento" though 1554 and 1560 read "venti."

[234] "impedimentum."

[235] Indeed, 3 to the fourth power is 81.

[236] And 2 to the fifth power is 32.

at the beginning, in accord with the excess of ten yards to the same. Likewise in connection with the height.

But there is another line of thought.[237] A gentler substance of the wind, and a similar movement, makes for the protection of sails. Just as a movement of collision,[238] of which a trembling movement is a part, tends strongly to cause tearing, so there is a fleeting movement such as precludes much &1074 in sails, as every motion occurs round something that is at rest.

The theory of keys is easier,[239] but of the same kind: when they are divided widthwise, only a small hook can be put in, so that when it is a little away from the axis, the bolt[240] cannot be shifted backward. Again, a long tightened[241] hook does not possess power and strength. Tougher bolts, and more of them marked out by partitions, are safer against hooks. A very secure door-bar[242] is one which has a catch[243] to be raised on one side of the key, and on the other a bolt, with a partition intervening between the catch and the bolt.[244] If I want to describe the kinds of door-bars here, the very topic will get boring. I will add an instance of one, which Ianellus[245] built. This could be accurately closed under any name which comprised seven letters, and could not be unlocked by any name other than the one used to lock it. Firstly, the sphere was solid, and from opposite a slight[246] channel was protruding in its front part straight from the centre; in its tip there was a short male screw. At the edge of this sphere there is another channel, empty, rounded, of equal size, and parallel; and opposite, two small lines mark a belt.[247] On these lines the seven letters of the word[248] are to be placed in a straight line, by going round and adjusting little discs, in the order which you have appointed as to be kept; for instance, so that the name of seven letters is to be "serpens," the individual discs will make up their letter straight along the interval between the two lines,[249] so that it can be closed or opened.

There will actually be seven discs on the edge carrying an &1075alphabet,[250] of which I have described one as a specimen in the margin; or the same in number

[237] "ratio."

[238] "concursus."

[239] 1550 reads "subtilior" here, not the "facilior" of later editions.

[240] "repagulum."

[241] "strictus."

[242] "sera."

[243] "obicem."

[244] The remainder of this paragraph together with the four subsequent ones first appear in 1554.

[245] See n. 82 above.

[246] "lenis."

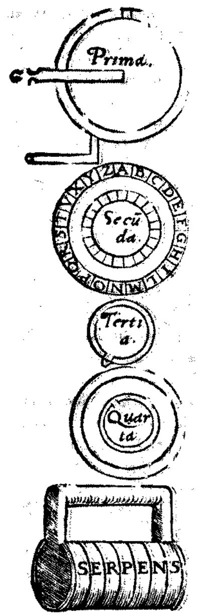
[247] "limbus."

[248] "dictio."

[249] "è directo spacii duarum linearum suam literam constituent."—syntax uncertain.

[250] "alphabetum": probably means "an alphabetical letter."

as the number of letters under which it is to be closed. In the middle is a broad circle marked out with as many intervals as there are letters in the margin.



Also the same number of toothed discs as there are ranks of the alphabet. I have set these out in the third figure with the addition of a tooth; or, as in the fourth figure, the back part of the discs of the second figure, with a gap in the middle of the disc, at which the tooth of a little disc is inserted. It is evident, indeed, that with the second disc &1076 turned round like this, it will draw the third too along with it, and yet only by fixing the letter in its place can one disc be joined to another or detached from it. When the door-bar has been closed, the discs turn without obstruction, so that the sequence[251] of the name is mixed up.

But let us leave this, which is more curious than useful; let us rather explain something relevant to daily life, that is, the way in which cash can be hidden in a chest so that no trace of the place can be seen, nor if it gets known can cash or jewels be extracted without smashing the chest. To know that they are there is an advantage to many people; even if they do not know where, they anticipate, they search, and sometimes take such liberties that they set about breaking it; nothing kindles the daring of thieves and robbers more than knowing and finding out for certain that there is booty at hand, even if they do not know precisely where it is. And on the other hand, nothing so damages their daring as wondering whether the booty is there. And so for security special effort is needed for the nest to be undetected; then even if they know it is at hand, to make it as hard as possible to take out. No one is unaware that iron material and thickness of panels are essentials. Then there are everyday things: a double bottom for the chest, or small chests at the sides, and concealed little letter-cases[252] and hidden recesses, none of which can fool a man of discernment when he has compared the thickness of the parts and sides [624]together. So a small opening has been made in the sides or the angles, in a downward-facing place, and inside there is a cavity in a panel as large as we wish; indeed, more cash is shut away there, and the cavity &1077 is filled up with flock,[253] then with very fine sawdust, and where the opening is gets closed with eggwhite, so as to deceive even the man who shut it up. Another method: a panel closes the cavity so tightly that no crack appears.

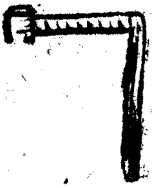
In a section which can be removed, a small metal female screw is enclosed, and a key is placed over it; other ones like it are arranged throughout the chest

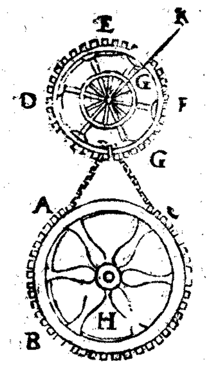
251 "ratio."

252 "scriniola."

253 "cottum."

in a definite order; when the place is to be unlocked, a male screw is inserted, with the key removed, and the piece of the panel is removed. You always bear in mind that to prevent the empty space resounding when you put anything on it, it is filled with flock or other soft stuffing. You can make a number of hiding places like this. Another expedient that is very good, as good as any: connect a door-bar or iron leaves, by which the covering of the chest is held on, firmly to a panel with keys adapted to the shape of a screw. Under the bar or leaf there are to be small orifices of cavities; when you want to unlock, have a piece of iron (as illustrated on the side) [*sic*] with a cavity in its end, which grasps the heads of the keys tightly, so as to allow the door-bar to be forcibly turned, or the leaf to be separated from the chest. The work must be steady, to bring female screws close up to the keys — female screws that are to enclose the keys tightly, and to place the screws on the side of the chest under the so-called leaves.[254] In the case of chests that are lined inside with cloth, many other methods can be devised, but overall, effort is needed for the opening either to be hidden altogether, as we explained in the first example, or to have very strong protection, and be hidden by the usual leaf. It will be more concealed like that, and the openings of a chest capable of being taken apart[255] should be covered over by the inserted tops of the panels.





&1078 But let us return to the account of wheels. Gems are engraved and perforated with marvellous skill. This is how it is: a large wooden wheel has a rope round it, and the same rope is also round a small one, which is mounted above the large one, wheels drawn on the pattern you see at the side.

Then when all of the portion AB of the rope ABC, the same size as DEF, is moved round, the small wheel G is turned. AB is contained so many times in ABC — the little wheel DEF will be turned that number of times in one rotation of the larger wheel, which is called H. So the ratio of the size of the circumference or axis of H to the circumference or axis of G is that of the number of revolutions of G to the number of revolutions of H; so G will be driven round with the maximum impact, because this will be done in the shortest space of time; consequently the axle GK will perforate and shatter gems. On this plan, with teeth created in G which push round the axle of the other wheel, being meshed with its teeth, the bigger the wheel was, the faster it would turn. Hence with the pattern of the larger wheel being repeated frequently, then the motion of the axle will become very rapid and vio-

[254] "bracteas," probably the same items as the "laminae" earlier mentioned.
[255] "solubilis."

lent; but in such a way that the force doing the original moving is very sturdy and the wheels very light.[256]

The ancients employed the same subtlety in constructing ballistas (which discharge balls) and scorpions (which discharge arrows); if they are over-stretched, they break up; if under-stretched, they deal weak blows. &1079 So the question needs a measure.[257] Vitruvius thinks that this level[258] should be estimated from the sound.[259] These projectiles used to be propelled with such force that Josephus records that a man's skull was shot away by the device, and projected three stades away. And an infant was shot out of its mother's belly to a distance of half a stade. The Roman talent was so cunning for slaughter that they came close to the marvels of our modern thunderbolts. And their battering rams for demolishing walls came second to our artillery on the basis of inconvenience, not that of lack of power. Many things have grown out of use when better ones succeeded them, and others through lack of care— some of them because no measurement or weight could be permanently preserved; weight assumes a fixed measurement, and all measurement must be measurement of something. The item of which the measurement exists must not change, if a future measurement is to be permanent. And what must not change is either celestial, or originating from elements, or is an element, or a part of it. Items originating from elements differ according to the ampleness or scarcity of their matter, not just according to the seasons, but according to places and circumstances. As I have said, tall men have now been found in India, and with the form of giants;[260] others so small that you might call them midgets. And Germans are bigger than Italians; and among the Germans the measurement is not consistent, since some of them are small. What about stones?—are we to look for a definite size among metals? And seeds too vary: Turkish wheat is far smaller than ours, but perhaps of a different kind. In Italy it is not of the same weight everywhere, and it changes in individual years, and is not of one size even in the same heap. And things are not all the same either in motion: what gets moved is a weight larger or smaller, but this is not yet &1080 fixed; or it is an animal, and this in similar fashion is either greater or smaller, or weak, or sturdy or energetic. Nor are things all the same either in the heavens; since they are very large, measurement cannot show of what sort they are, not just

[256] 1550 and 1554 include here, "This is the origin of the measurement of clocks, with the later wheels dividing up the primary movement."

[257] "modulus."

[258] "meta." Vitruvius (*On Architecture*, 10. 12. 2; Loeb 2: 341) remarks that when the twin ropes of catapults are correctly and equally stretched, and then struck by hand, they emit an equal note. "So by the application of wedges, the catapults are tuned to the right note by a musical ear." If not, the shot would deviate from its intended trajectory.

[259] Material from here to [C] on 1083 (1560) first appears in 1554, and 1550 includes at this point a paragraph about two plane surfaces in apposition and the vacuum.

[260] Book XI, at 809 (1560): "in the New World an island of giants has been found."

because of their size, but also of their distance. So they need to be assembled;[261] and what does this is exposed to corruption; something like that does not stay the same for all time. So no measurement standard, and much less any weight, can be called permanent or can pass on to posterity. What does so is proportions, and they are eternal, or the sizes in masses, and the weights along with them—these last a long time, through replacements.[262] This is so in the case of the Pyramids of Egypt; they were very large, like the Labyrinth at Thebes,[263] and like Cairo among cities, as mentioned previously,[264] and among rivers the Nile; these four are very large, and only Egypt has them. If anyone establishes for reliable measurement the hundredth part of the height or width of a particular [625]pyramid, it will constitute a definite weight[265] in the eyes of all races and for many centuries and with a measurement made.

Another plan is derived from the replacements of corrected books.[266] For instance, at Rome Serlio[267] observed the ancient measurement of a palm, which had passed on to posterity. It was accurately transferred to his book, and from that, we have placed its middle part here in ours, as you see in the margin.[268]

&1081 In this way a measurement to last for many centuries can be taken from the height of the columns of the greater church at Milan, the most revered in

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261 "contrahentur."

262 "successiones."

263 See Herodotus, *Histories*, 2. 148: two of the kings of Egypt "decided to leave a common memorial of their reigns, and for this purpose constructed a labyrinth a little above Lake Moeris . . . I have seen this building, and it is beyond my power to describe; it must have cost more in labour and money than all the walls and public works of the Greeks put together . . ."

264 In Book VIII at 553 (1560), Book X at 691 (1560), and Book XI at 806 (1560).

265 "certum pondus"—but it is not clear why a *weight* is mentioned.

266 "codices."

267 Sebastiano Serlio (1475–1554), major Italian authority on architecture. His books on architecture were originally published in the 1560s.

268 For the *Roman* palm, E.W. Marsden (*Greek and Roman Artillery* [Oxford: Clarendon Press, 1969], xvii–xviii) draws on F. Hultsch (*Griechische und Römische Metrologie* [Berlin: Weidmann, 1882]) to present a length of 7.39 cm. Pauly-Wissowa (1st ed., vol. 18. 3) offers about 7.5 cm. But for his own time, Cardano here refers to a scale in his margin, the "middle part" of Serlio's. There is a scale in the margin of the 1559 (octavo) edition at the same location in text (609), measuring 12.7 cm in length, with 48 divisions, evidently the 48 "minutes" of a palm comprising four "digiti," each of 12 "minutes." This passage (and the scale) is absent from the earlier 1550 edition. Thus, ignoring the remark about the "middle part," for Cardano a "palm" apparently corresponds to 12.7 cm. However, the similar scale in the London edition of 1611 of *Serlio's Five Books of Architecture* (Book III, chap. 4, Folio 41; see Bibliography) measures 21.7 cm, still in 48 divisions. By 1710, Harris's *Lexicon Technicum* (vol. 2) describes the "palm" as "an antient long Mesure" and mentions that it "differs according to the different places where it obtains," offering equivalents ranging from 7 to 8 inches (18 to 20 cm).

Christendom, from a hundredth part, or some other. It cannot be taken from the length, since this is still far short of completion. Nor is the width entirely secure, either through the addition of ornamentation or through chance removing something. However, anyone who chooses the greatest width will not be wrong, since when divided into so many parts it can allow of no detectable error.

With this measurement established, the ratio of weight in terms of pure gold can be deduced—gold permits bubbles not at all, and its great perfection enables it to change less. Nearest to gold comes mercury, which does not permit bubbles either, and is very weighty, though not to the fullest extent. We need to take our measurement from the biggest things of each type, so that a smaller error may be encountered by those reaching very tiny measurements by subdividing.[269] This is why Ptolemy derived the motions of the stars from the most ancient observations he could; but as I said, this carefulness is good enough for a long period, but hardly forever; only things of three kinds can be eternal: either in their substance, like heaven, if indeed it is so; or in their succession, since they are so by nature, as species are; or like proportions and numbers, because an intellect's working differentiates them from matter. These have been discussed above, in the work devoted to them.[270] And now—a point concerning the present discussion—we must see whether among technical achievements perpetual motion has been provided.

&1082 There is no doubt that natural and perpetual motion exists in heaven. Similarly in a system[271] of succession, as in rivers, which move forever down a slope so long as water is produced. And the actions that proceed from these, as in the case of millstones, which are rotated by water. And it is not to be supposed that a perpetual motion can be sought from these to be really perpetual; over a long space of time, and especially if they are in motion, all natural bodies are eroded and destroyed. So is it an appropriate question, whether some motion can be found which embodies the cause of its own continuity, without any new generation? For example, in the case of clocks, at the place in their motion where the hours are indicated by strokes, if the weights were being pulled back up, the business would be over.[272] And so there can be only three kinds of natural motions by which heavy items are moved: either towards the centre *per se*; or not simply towards the centre, like waters; or from some influence of nature, like that of iron towards a magnet. Consequently it is agreed that the arrangement must depend on two primary points: there is a natural motion including some violence,[273]

[269] "dissecando."

[270] Book III is on Heaven.

[271] "ratione."

[272] This might mean that during the raising of the weights there is no torque to continue any striking of hours that might be going on at the time—and no doubt the counting of the hours would be thrown out of adjustment.

[273] In the technical Aristotelian sense.

when something is either pulled apart[274] too much or contracted[275] too much: these two types are visible in the springs of clocks. It is possible to find a starting point and an end point in every arrangement when it consists in a location.[276]

And things that move virtually round a centre after this, unless it suits heaven and the air, but this[277] irregularly, have a starting-point from something the same as those things that move according to a straight arrangement; water, as I said, itself also moves according to a straight arrangement. Then at last what is carried along must be returned once more &1083 when it is at its goal, if the movement has to be perpetual. But it cannot be returned, unless from a deviation.[278] Then either the continuity of the movement will happen from what is in accord with nature, or it is not an even movement. What is being reduced all the time cannot be perpetual, unless there is an addition. But now let us pass to other problems.

It had been remarked that there is subtlety in nature, and in the achievements of technique; there is also a third sort, that is, in the matter of the achievements themselves. [C] For instance, if there were a subtlety in textiles[279] linked to compactness, it exhibits a better and longer-lasting product for its weight. Thus in sarsenet[280] there are two thousand threads in the width; the width or size is an arm's length, and how much that is has been shown earlier; it is woven obliquely, not crosswise.[281]

I have seen a kind of clothing with thinness of its web, so subtly constructed that it cannot be bettered for keeping out water; it is called "Bernucium."[282] Similar to it is "Beni," made from camel hair, but rather thicker, repelling water from itself, so as to hold it out like a container; it is imported from Asia. More elegant is the very light and thick fabric made (so they say) from ash-coloured beaver

274 "trahitur."

275 "contrahitur."

276 "in omni situ cùm loco constet."

277 The air, evidently.

278 "excessus."

279 "contexta."

280 "sarza." The English word "sarsenet" means a fine silk textile, and both words stem from the same origin as "Saracen." It should be noted, however, that one work of Cardano's is entitled "De sarza parilia" (at *OO* 7: 271–74; Maclean, *De libris propriis*, M72 [81]) but is entirely concerned with the medicinal uses of a *root*, and there is no mention of any fabric. The same material is discussed in M42 as a cure for the "*morbus gallicus*" (syphilis).

281 This sounds like "twill," but the diagonal lines on twill are not due to the thread actually crossing obliquely; they are due to the points at which the transverse and vertical threads intersect being subtly changed as weaving proceeds vertically, so that diagonal stripes appear.

282 The previous sentence appears first in 1554, and the remainder of this paragraph appears first in 1560.

hair. I have caps made of it, but it suffers readily from moth, and also absorbs water—attractive only for its lightness. Cowls[283] are better than caps, because the water runs off faster, but they foul the clothing, by shedding their hair easily. They are imported from Poland, and are dearer than any of the others. Thus in all natural products thinness begets &1084 not just elegance but also strength and solidity, because the parts hold together excellently, just as in thin sand;[284] it is accepted that for such a small item, it made so much profit at sales.[285] But at one moment it is their nature, at another it is the technique that contributes a part—nature certainly, as in the case of fine flax,[286] it being a sort of linen which used to originate in Elis, and was of such thinness that on the evidence of Pausanias,[287] it would be exchanged for its weight in gold. Indeed, strength and a glint used to accompany this thinness; when these two are present, they make everything more costly. And the same art deserves imitation — art is the imitator of nature. But just as in natural things, so in those created by art, the textiles and what is included in the texture meet their own standards of thinness.

In the same way, in the case of items reckoned as in themselves very thin, another system for thinness is found; for instance, when clothing or thread is fouled by a stain: they are wiped with lime, or oak ash, or tartar, or lemon, or soapy liquid; these can be used in combination, or even one at a time. No wonder, since sharp white vinegar can do this.[288] Of the same sort are ox gall, and common alum, and the salt called chali,[289] and agents that glitter of themselves; [626] these are mentioned elsewhere. There are also some waters that are prepared by distillation, like borage water.

But in all cases, technique is required in addition to the object[290] itself; for instance, in spot removal, one should wash down first, then squeeze out vigorously, and again moisten and squeeze out; when you have done &1085 this four or five times, you will see the garment immediately cleansed of oil or fat. But take care in case the colour has departed because of cat urine;[291] a stain will then appear which is not a real one, so then you should restore the colour, not wipe

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[283] "penulae."

[284] This may mean that very fine-grained sand when damp has more coherence than coarse-grained. Alternatively, the sand may be used for casting molten metal.

[285] The following three sentences first appear in 1554.

[286] "Bissinum."

[287] "Most of them (the women from Patrae, on the south side of the Gulf of Corinth) gain a livelihood from the fine flax that grows in Elis, weaving from it nets for the head as well as dresses" (Pausanias, 7. 21. 14; he says nothing about the gold).

[288] The following two sentences first appear in 1554.

[289] On chali see n. to Book V at 379 (1560).

[290] "rem."

[291] Cat urine had destroyed three of Cardano's books in preparation: M10, M11, and M14 in Maclean, *De libris propriis*, 50–52.

the stain: crimson[292] with the berry dye,[293] reddish with brasilium,[294] blue with indigo, and woad,[295] but with added violet, without which the place is green, as rusty[296] wood with brasilium, saffron yellow with indigo and woad, and dark with blacking. People say that fatty stains are strongly removed by the very fine ash from the bones of castrated animals, when it is sprinkled on the stain for twenty-four hours and squeezed between boards and linen cloths.

But you will say, "Why can what works on all the other colours not wipe away stains in shiny white or saffron yellow? Is it because agents that wipe away, being powerful, make another stain on the white?" But in saffron yellow they remove the proper colour; yet there are agents that are capable of removing stains in all materials—only the method and the material[297] differ in linen, wool, and silk.[298]

However, there are items that are not responsive to a single sort of technique, even if they are made with wonderful subtlety; for instance, if you set out to put a book quickly into order, you will make another book, out of harder paper, paper toughened by a slender mallet. Then use a strong double or fourfold thread, pulled from the top to the bottom and linked on both sides, and take two copies thoroughly alike, beside the form of one type,[299] and you will split up the sentences, of one from the front, of the other from the back, and you will place them below those you wish, between the threads and the paper,[300] and alter and transpose, add and take away, &1086 so often till the sequence not just of the sentences but also of the words comes right in all directions. Then take up some glue and attach the portions of the booklets to clean paper. Thus you will bring the whole book into better order by working during three days, and more easily than if you had slaved for a whole year transcribing; often the previous rearrangement will not be satisfactory when a better one is on offer. In this rearrangement, the place of the alteration is always evident.[301] There are many expedients of exceptional subtlety in this category, and of outstanding usefulness, but to add three

292 "purpureus."

293 "coccus," usually translated as "scarlet."

294 On this see n. in Book VIII at 584 (1560).

295 "glastum."

296 The word "schuodenum" appears here in all three editions consulted, but its meaning cannot be found.

297 "res."

298 1550 includes here brief advice on cleaning teeth, removed in 1554.

299 In printing, a "form" or "forme" is type and blocks fastened together in a frame, ready for printing; this may not be relevant here.

300 Syntax obscure: "dividésque sententias, unius quidem à fronte, alterius à tergo ac quas quibus voles subiicies inter fila chartámque, totiésque mutabis ac transpones, adiicies, demes, donec ordo non solum sententiarum, sed et verborum undequaque conveniat."

301 The material from here to the top of 1092 (1560) appears first in 1554.

examples will suffice: with these four as guides, everyone will be able to satisfy himself in other cases too.

The first is when you want to reduce some medley to an established order on a definite plan, for instance that of another book. You will prefix to each the numbers from unity, in order of numbers; and you will split up the whole medley into ten parts, or nine or eleven, and reduce the whole to those headings. Prefix to the first 1, to the second 1, to the third 2, and so on in succession, so that apart from the initial unity, it is to be added to the remaining points. Those that are contained under the initial unity you will reduce again to order; in fact these will have been few, from one to ten; if very many, from one to a thousand, if middling, from one to a hundred. In this way those that are placed under 1, if few, from ten to twenty; if very many, from a thousand to two thousand; if average, from a hundred to two hundred. You will go ahead in the same sequence after 2 in the case of those that are placed under that mark, till you have reduced it all to exact order. Afterwards, you will prefix other numbers corresponding to the sequence of numbers, larger ones to larger ones, &1087 lesser ones to lesser ones, so that those equal at the start are equal in the final rank, yet not corresponding to each other. Remove all intermediate numbers; then you have left to you two ranks, the first and the last, which you chose to extend just to ten, for the sake of brevity. The first indicates the order in which the medley was written, the last, that in which it should be written. So to convert one to the other, you will write in series the same number of numbers on another tablet, so that the original rank becomes that of the second tablet. So in the original rank of the first tablet, look for each number to which it corresponds from the end of the first tablet, and look for the one to which it corresponds in the second tablet in the first rank (this is very easy, since the numbers are laid out there in the natural sequence), and when that is found, place opposite it the number in the first rank of the first tablet. And thus you will complete the task[302] in the minimum space of time, since you will find without difficulty the three numbers you are seeking: those of the first tablet of the first rank, because you always progress by moving down; those of the last rank, because they are from the region of items found; those of the first rank of the second tablet, because they are arranged according to the natural sequence of numbers. As in the example: I first find in the first rank of the first tablet "1," from the region I find "7," I look for "7" in the first rank of the second tablet, from whose region I write "1." Then I find "2" in the first rank of the first tablet, directly opposite which I find

Tabula prima

Vlt.	*Primus*
7	1
3	2
2	3
1	4
10	5
9	6
6	7
8	8
5	9
4	10

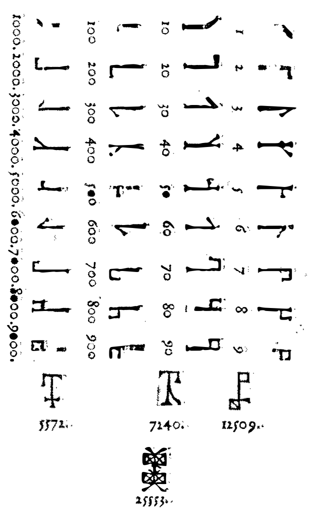
Tabula secunda

Pri.	*Secundus.*
1	4
2	3
3	2
4	10
5	9
6	7
7	1
8	8
9	6
10	5

[302] "rem."

"3." I look for "3" in the first rank of the second tablet, directly opposite which I write the "2" found in the first rank &1088 of the first tablet. So in this way the second tablet is completed; the first rank indicates that it needs to be dealt with first; the second indicates when the one we wish to deal with on the facts needs to be taken from the medley. Then all the numbers of the last rank of the first tablet need to be deleted.[303]

A second instance of subtlety in this is: when you want to add something to a book already written, you will do so conveniently if you have marked the details you want to add with a preserved series of numbers, and you have written the same number in the place in the book to which they need to be transferred. But if, when this addition is complete, others turn up which you do not want to overlook yet do not want to transcribe, make another little book with numbers prefixed to the individual additions in a natural order; but if the first addition has not exceeded one thousand, the numbers of the second addition will start from one thousand, and will [627]advance further in order. And similar numbers must be written in from the region, in place of the earlier book or of the first addition to which the addition belongs. And thus, if adding new material is needed for a third or even a fourth time, you will start the addition without any labour or muddle from the third or fourth set of a thousand. You will do just what you did in the first and second. As the work has proceeded, if you wish either to read it or to transcribe the whole mass in sequence, take up the first book[304] and skim through it till the number turns up. When it does, if it is 1, the first addition of the first supplement is to be read. If it is 1001, the first addition of the second supplement is to be picked up. If it is 2001, the first addition of the third supplement. And if &1089 while reading this one, for instance, you find 1002 from the neighbourhood, then the second addition of the second supplement should follow after it. And thus without hindrance you can reduce to order any number of supplements of additions, one after another, and without muddle—and once in order, you can enjoy reading them.



Perhaps for this it will be more convenient to use the Indian symbols for numbers[305] than the old-style ones.[306] And I have found a way to search and correct a number of copies at once (so long as one has been written down from

[303] This procedure is very difficult to follow.

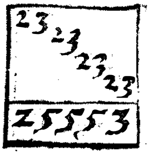
[304] "codex."

[305] I.e. those now called "Arabic."

[306] I.e. Roman numerals. The three following sentences first appear in 1560.

another in the same series), and each needs a listener. Compare the last with the first; if all is well, all the intermediates are all right too. If an error is present, move back towards the first from the last, altering the individual copies, till you reach one that agrees with the first. This is a rather important kind of procedure; similarly, what follows is rather useful—I could not possibly say how much it has helped me in watching what I was reading. The discoverer of this idea could be passed over in silence, since I cannot tell whether in those three books that he wrote on the *Occult Philosophy*[307] there is anything else that is true, he seemed to me so crazy while he was writing this—much more so than its author in the *History of the Danes*; I do not know who the Saxo Grammaticus[308] was who wrote that history all full of fables. However, I would not wish anyone to be deceived by his own inventions. That Cornelius Agrippa[309] with so many first names is the author of this fine detail.[310]

However, I have not followed him precisely even in this, because he was no more careful &1091 in this matter than in the rest. This is a system[311] which is better explained by a table set in front of one's eyes than by a long speech. Suppose for instance that I want to write down 5572 in this way. And if I were to want to write 7240, I do it as you see in the margin. And if I want to write 12509,[312] I will write first 9000 by its own shape, then placing a multiplication sign across,[313] which means 3000, I will have 12000, to which I add 509, and I shall have the figure you see in the margin.



But if I wanted 25553, which is the largest that can be written here without confusion, you will get it in the way that I have depicted it finally. The individual parts gather 23, hence if they are added, as you see at the side here, this will make the number 25553.[314]

[307] The author was Henricus Cornelius Agrippa; on Agrippa see n. in Book XV at 937 (1560).

[308] Saxo Grammaticus: probably born in mid-12th century and died early in the 13th century; Danish author of a sixteen-volume *History of the Danes*, first printed in 1514. Items in this furnished a major source for Shakespeare's *Hamlet*. See *Gesta Danorum*, ed. and trans. K. Friis-Jensen and P. Zeeberg (Copenhagen: Danske Sprog- og Litteraturselzkab, 2005); trans. H.R. Ellis Davidson (Woodbridge: Brewer, 2002).

[309] See n. 307 above.

[310] "subtilitas."

[311] "ratio."

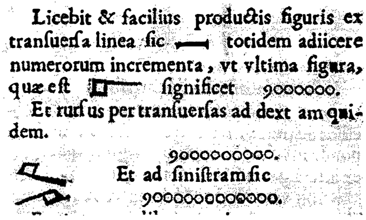
[312] The Figure from the *Opera Omnia* edition, which may be shown here, reads "12529" but 1560 reads the correct "12509"

[313] "ducta transversa," the little X on the rectangle of the sign for 9000.

[314] But despite Cardano's explanation, it is only partially clear how he arrives at the representation of 25553 displayed here, and at the representation of the even larger numbers that follow. There is an upper limit to the number that can be expressed in the system he describes here; it is noteworthy that the introduction of the "Arabic" numeral system,

It will also be possible by easily producing figures from a transverse line like this — to add the same number of increments of numbers, so that the final figure, which is , indicates 9,000,000. And again, by cross lines to the right.

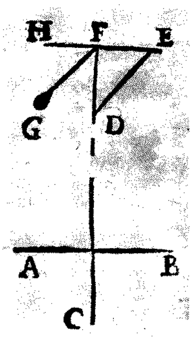
9,000,000,000 and to the left thus: 9,000,000,000,000.


Licebit & facilius productis figuris ex tranſuerſa linea ſic totidem adiicere numerorum incrementa, vt vltima figura, quæ eſt ſignificet 9000000.
Et rurſus per tranſuerſas ad dext am quidem.
9000000000.
Et ad ſiniſtram ſic
9000000000000.

And thus I can express any huge number without confusion, by fingernail alone and with straight lines.

But Agrippa barely reaches ten or twenty thousand, and these numbers with effort and confusion. However, we owe that to him.

&1092 There are people who have taught the blind to write in this way: a brass tablet is engraved with hollowed-out letters in alphabetical order; on it the blind person moves his stylus element by element, holding their order in memory till through long practice he learns to write the same with a pen.[315] Erasmus[316] records that several people had learned to write correctly in this way, though with huge effort. This business needs a diligent supervisor, and long practice. And when the stylus is very sharp and the wax layer[317] thin, they learn more easily and better. The achievement is very extraordinary, but not so useful. For example, I recall having seen someone who entirely lacked arms, and used to shake a spear with his right foot, and point it, and sew clothing, and eat, and write, and thread a needle. I trust there will be no lack of witnesses of such a miracle, since the issue was of public interest. To return to the devices: a tool is made from which you hang yourself by your hands, and while you pull, you are pulled more strongly. It is constructed thus: AB is an upper pavement, the start of the pulling rope is C, DE is wood or iron bent with great force, and a rope CD is attached to it. DF is wood underlying the ceilings, and prevents ED from returning. To FD is attached a weight GF, [628]so that FD can be rotated towards E whenever FD is not being pressed by ED. For FD is fastened in a ring; then when CD is pulled, FD slides back&1093 towards E, but from the side because of



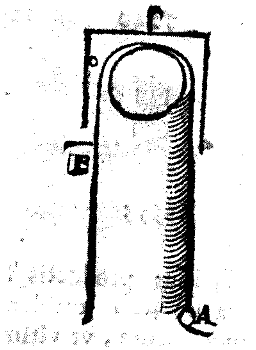
with its zero, bypassed upper limits and the expedients required to raise them. It is evident from Nenci's edition of the present work (e.g. 258–59) that the earlier editions it cites generally used Roman numerals, but the later ones used "Arabic" numerals.

315 The following three sentences first appear in 1554.

316 Erasmus, *De recta latini graecique sermonis pronuntiatione*, ed. M Cytowska, in *Opera omnia* 1. 4 (Amsterdam: North-Holland, 1973), 39.

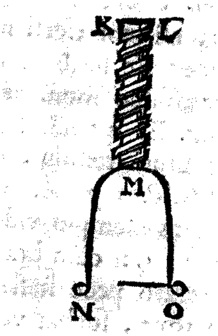
317 "litura."

the weight G, so the iron ED, which was being held back by FD, will slide back to the ceiling HE, pulling DC upwards.[318]



A tool capable of pulling a man upwards easily: a pulley with an iron hook, in it a ring of the usual sort, around which is a rope, on the rope a weight A, a little less in weight than the weight of your body; on the other side a transverse stick B. Then with the hook attached you will pull on B as at A below, the weight will move up, and reach B below. Then sitting on B, and on the other side holding AC with your hands, because the weight A is a little less than the weight of your body— A will descend again, while you go up with great ease; when you want to descend, you will do this of yourself, your body being heavier than A, so letting go of the rope, you will descend in a rush.

Agrippa's device is another one. He used to make twin tongs, entirely identical; you can see a picture of one printed in the margin. KMO and LMN, pieces of &1094 steel, are linked at M, with a rotating movement round a pin, and they make one complete pair of tongs; the upper parts KM and LM meet in such a way that when they are squeezed, one enters into the other, reproducing the shape of a screw. Between them there lies a rope, when it is in use. The straight pieces NM and OM have a ring at the bottom, into which a strong cord MO is introduced. This is its use: as I said, the rope is gripped with KM and LM, and by narrowing NO, it is narrowed when a foot is placed on NO; the heavier the body, the more NO will get curved, and the more tightly the rope will be constricted by the tongs. So the heavier the person climbing up, the safer his ascent. Then you will link another tongs, a cubit[319] taller, to the first rope, and by putting in your foot while you raise the other one, you will remove the lower foot and the lower tongs, and you will place it the right amount[320] above the second one, and thus you are climbing up safely, as though on a ladder, right to the top with a single rope having a hook and two tongs; the screw shape prevents the tongs slipping through the rope, because of oversight.



But this way of getting up is quite unsuitable for getting down, if compared to other devices. So he invented a very easy way of coming down. A screw of

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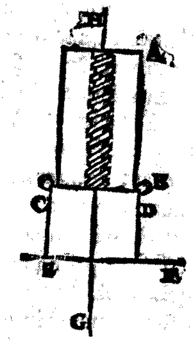
[318] This is very difficult to follow. As Cardano himself presently remarks on 1098 (1560): "This is why many people will read this, but few will follow it; one should grasp more than what is written down, even though nothing is short of perfection."

[319] See n. to 26 (1560) in Book I.

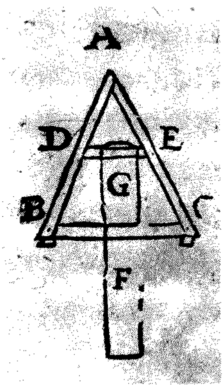
[320] "tantundem."



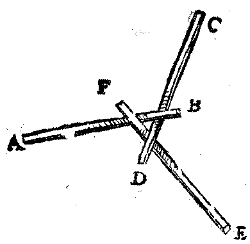
steel, of a palm's length[321] and hollow inside, so as to be able to receive a rope HG, is to be named AB, and round it a light casing above of brass,[322] perforated below. At the bottom its two attachments, in which are the cords C and D &1095 [wrongly numbered 1079] supporting the iron rod EF, and when the person to come down is sitting on it, he will come down very fast and without any inconvenience. And if he pulls the rope G down, or pulls ABC to himself, the screw will not move down, because stretching straightens out GH and does not allow the screw to slide. Similarly, when he pulls G to himself and it is turned upwards, he will not move down in any way, but be stationary, without effort.[323]

The sailors know this too — sitting on a simple stick with a rope wound three or four times round it, they come down holding the rope G, and if they release it gradually, they come down, but if they pull hard on it, they remain at rest seated. This matters, because those who sit on a stick easily fall, since they are tilted because of the rope being on a slant, unless they are experienced and confident. But this device (I have seen it and handled it a number of times), always being in equilibrium at EF, is not frightening, and anyone however inexperienced can sit in safety on it.

However, now that I have sufficiently explained the theory of machinery and weights, so that no further postscript seems needed, is there a need for a theory of a device commonplace but of marvellous strength? It is used by those who cut timber, and it supports a beam, and a man on top of the beam, and in addition the impact of the saw coming down. The device ABC consists of timbers lashed together and secured by wooden pins. Below B and C are little feet smaller than a palm,[324] by which A is raised from the ground when the device is placed on the ground;[325] DE is a pin riding on the beam; the question is, why when F is much heavier, it does not raise A, and fall down? The reason is that if it is straightened a little, with G the [629]protruding part being longer, it has a small ratio to the resting part, and so &1096 cannot raise it. If G is small, much less so, because E is less far from the vertical, and so increases the weight very little.[326]

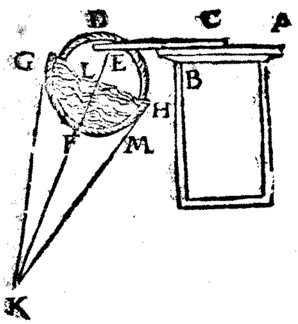


321 On the palm, see n. 268 above.
322 "aurichalcum"; see n. in Book II to 106 (1560).
323 The next five paragraphs first appear in 1554.
324 On the palm, see n. 268 above.
325 "quibus à terra elevatur A in terra posito" — syntax unclear.
326 I do not follow how this works.



There are things too that seem to be supported of themselves, and even support others with no bond between them. For instance, I take AB, I will pull it, and on it I place CD. On top of CD I put EF, in such a way that EF falls under AB; then I say that unless they are released, they cannot fall—AB is supported by FE, and EF by CD, and CD is held up by AB, so none of them will fall. The location BDF is supported, and supports; from experience this is clear, so it is supported by something, and so by everything, since everything is on the same basis—so is it very secure? The more it is pressed upon, the more secure it is, and it does not split, unless broken by one of these.

We have spoken about things that support more than the ratio appears to explain, and about things that support each other mutually; now we need to show how something &1097 appears to be self-supporting. Let there be a flat slab,[327] and a stick CE, whose outer part is under the handle D of a water-pot[328] GFH full of water, and between the stick CE and F (the bottom of the pot) will be placed a straight piece of wood EF, snugly, so that it cannot slip out: I say the pot hangs and does not fall; it is agreed that since F is the bottom of the pot, EF is the stick, and F is the centre of gravity, and the earth's centre is K, and the pot's centre is L, they are in a straight line, which is KFLE. So if the pot falls, it will do so either along the straight line FK, or some side (such as G or H) will be tilted first. If then it is tilted towards H, into M, I draw KM; so because two lines come from K, KE and KM, to a circle, and KE, it passes through the circle's centre, that is, of the pot—from the proofs by Euclid in the third book of the *Elements* KF will be less than KM. So the centre of gravity F is at a distance from the earth's centre K, and the weight[329] rises by natural movement on its own—which is impossible. So the pot does not go down by tilting itself towards some direction. But nor does it do so along the straight line KF, because the angle FEC is a right angle, and constant; as D moves down towards L, let LB be drawn; so EB is equal. So when LB is set opposite at a right angle, either through the fifth proposition of the first book of the *Elements* the triangle LEB will have two right angles, or the greater side will not lie opposite the greater angle, and both of these are in opposition to what Euclid demonstrated in the first book of the *Elements*.



327 "abacus"—can mean a slab or sand-table or board for playing games (*OLD*).

328 "situla."

329 "grave."

What follows from this is a greater miracle, which is, that something about to fall of itself does not do so after the addition of weight: when the part of the stick BD, larger than DC, is set down, the stick will fall, because in its fall its end approaches K, the earth's centre, and so C will be able to be raised, and &1098 so will fall; and yet, with the weight of the pot added, it will not fall. You need to be very careful, in case the trial fails, to the amusement of the spectators; when the thing does not succeed, uneducated people do not blame the man, but the explanations:[330] first, see to it that the upper surface of the slab is perfectly level, and the piece of wood exactly straight and not flexible; and similarly that the piece of wood EF is straight and closely joined between the bottom of the pot and CE, so as to make the piece of wood CE stick tightly to the handle D. And that the point F is the centre of gravity, and the pot is rounded. This is why many people will read this, but few will follow it; one should grasp more than what is written down, even though nothing is short of perfection.

There are also serious uses of the art of medicine that are derived from subtlety. The first use is from the mixing of medicaments, through which harmful powers come to lie hidden, and the rest are distributed to the appropriate parts of the body; physicians are convinced that hot medicaments are attracted by cold parts of the body,[331] and cold ones by hot parts. Thus dry ones are attracted by moist ones, and moist ones by dry ones, and on the same basis, our body uses secondary and tertiary qualities,[332] in addition to these primary ones.[333] So it is a task for this book to explain how they do this in diverse parts of the body, and even without that celebrated[334] wonderful attraction and wisdom.

So let there be pepper mixed with lettuce, and let someone who consumes this have a cold stomach but a hot liver: it is evident firstly why this food or medicament will chill, and the lettuce, but not the pepper, will warm the liver; in the stomach, the pepper is already chilled, but the &1099 lettuce is made colder, and it is reinforced in its own coldness. So there is nothing remarkable about why pepper does not warm the liver, but lettuce will chill it. The only problem is, why lettuce does not chill the stomach, since it has itself undergone nothing from anything else like what pepper has undergone from the stomach. First of all, it is warmed by the pepper as much as, or more than, it is chilled by the lettuce. Then, if the stomach is colder than the lettuce, it will be reduced by both towards

[330] "demonstrationes."

[331] "membra."

[332] "Tertiary qualities" is the term used, for instance, in the work of Nicolaus Oresme (b. ca. 1320, d. 1382) to describe qualities which are not primary (the four qualities directly discernible by touch: hot, cold, wet, dry), and are not the *tactile* secondary qualities such as hard and soft, but are discernible by other senses. See Maier, *Grenze der Scholastik*, 14.

[333] The following eight sentences first appear in 1554.

[334] "illa."

a temperate state. Finally, since the temperament of the stomach diverges more from pepper's nature, than from that of lettuce, pepper is more affected[335] by the stomach than lettuce is. And the principle for the other qualities appears the same as for the primary ones. It is accepted that there are four primary qualities: hot, cold, moist, and dry—named thus[336] either because the rest flow from them, or, as Galen believes,[337] because they are the only ones that reach the inmost parts, and their action as primary qualities is to render a thing like themselves: a soft thing is not made soft by contact with a soft thing in the way that a hot one is made hot by contact with a hot thing. Among the primary qualities, heat's power is more apparent, then comes that of cold. Moistness is more suited for being acted upon[338] than dryness, which is why all living things are made up of hot and moist, because for a double reason actions in these are stronger: since heat is more suited than cold for action, and moist than dry for being acted upon.

Furthermore, the tasks of heat are to heat up, thin out, scatter, [630]concoct, soften, make rarefied, digest, dry, and finally burn up. Those of cold are to chill, constrict, restrain, render hard and raw, moisten, freeze. Those of dryness are to dry, and &1100 render rough and hard. Those of moistness are to moisten, to render smooth and soft. Otherwise, cold condenses (of itself; heat does it *per accidens*), while digesting all the time anything very thin, and it leaves it thicker. While heat is heating, it dissolves, and its own work increases—cold obstructs it, by making denseness. This is why, as shown above, the activities of heat are greater than those of cold, and more obvious and faster.[339] It was previously shown that since heat is a celestial quality, cold is mere privation, and appropriate for an element. Moistness is a quality of an element, and deprivation of it is dryness. The activities of deprivations are, so to speak, obstructions, not accomplishments.[340] They are referred to in two ways, either in association with substance, or without it. For instance, "hot" is a spirit, its quality is heat. From "hot" heat proceeds, in accordance with the resemblance, and "hot" is named from heat, but is not made from it. "Hot" is when heat is inserted from generation

[335] "maius patitur."

[336] I.e. named primary, presumably.

[337] Cardano's apparent suggestion here that other qualities exist which do not reach the inmost parts is not entirely in accord with Galen, who believed that the early processes of digestion "depend upon a *change of qualities*; similarly also the digestion of food in the stomach involves a transmutation of it into the quality proper to that which is receiving nourishment" (*On the Natural Faculties* 3. 4; Loeb, 241) In the same treatise (1. 6; Loeb, 21) Galen discusses "derivative qualities," of which a variety were held to exist. Cardano discusses primary, secondary and tertiary qualities further just below, at 1101–2 (1560).

[338] "in patiendo."

[339] The remainder of this paragraph, the following one, and the first sentence of the next one first appear in 1554.

[340] "effectrices."

itself, as in the case of a human being or a plant. Then fire is hot by name, but is really pre-eminent heat; fire is no substance, unless insofar as something is corrupted. What is corrupted is not a perfect substance either, but is changed; nor is it fire, but the subject of fire. So no quality is effective, properly speaking, except heat. Moistness is active because it is mingled, or else because it prevents.

But you will say, "If dryness does nothing active at all, why does what heats with dryness act so much more violently?" Because it does not have moistness to obstruct it. Again, if it is moistness that hinders, and dry heat is pure, then since celestial heat is pure, it &1101 will be dry, and consequently will not generate; it was shown previously that dry heat generates nothing. But celestial heat is pure in itself, but when mingled with an element, it becomes moist. But the heat that is not entirely mingled is dry; it is not mingled, because when abounding like this it is not suited to generation. So not all pure heat generates, but the heat that does is pure, and hence what is pure has mingled itself with an element; and because it has done so, it has become moist, that is, mingled with matter; all the matter of an element is moist, but earth less so, for otherwise it would not hold together.[341] Heat cannot be at rest, but has to be linked with movement; it is a quality in an unlike thing, hence it cannot persist, but can generate something else; generating is in substance; so what is mingled should by motion generate a like thing; what is not mingled should pass across into an alien nature; hence when dry heat is not mingled, it is pure from matter, but not from alien quality. It is thus clear that the heat of fire, and the heat that is aroused in animate beings by movement, is dry; and that dry heat is impure, yet not from its matter, but from an alien quality, and hence does generate something pure, but fire generates nothing.

But, as I said, both in the case of heat, and in others, many things appear to happen because what prevents is removed. So the four qualities that come to be in addition to these and from them are called secondary; to thin out, to burn, to pull, to make what is soft rough and loose-knit. Tertiary qualities are to cleanse the blood, to generate semen or milk, to be good for the eyes, or for sexual intercourse, or for sterility.[342]

&1102 Primary qualities are the substances of the elements, in mixtures partly substances, partly impressions;[343] the rest are called accidents. Four grades come together in them all, but in the first ones especially. The first is when the actual quality is dimly perceived. The second, when it is clearly perceived, but without inflicting damage. The third is when it does damage, but can be borne. The fourth, when it can barely be endured. Among the qualities of this grade, let opium be an example, among the tastes pepperwort, which is much more

[341] "non enim consisteret."

[342] "Tertiae sanguinem purgare, semen, lac generare, oculis prodesse, aut Veneri, aut sterilitati."

[343] Cicero used "impressio" to mean the (sense-) impression on the mind made by phenomena (*L&S*, *OLD*).

pungent than pepper. This is in each way: pepper will doubtless be placed in the third rank of sharp and heating things.

So when these things are mixed, the measurement should be retained so precisely that what is superfluous is discarded, what is harmful is concealed, and only what is useful remains; like that, an excellent medicament will be built up, very powerful at helping, and what must harm is utterly lulled to sleep. This is known from experience, hence (wrongly in my view) Galen was led by daring ambition to add something to the theriac of Andromachus.[344] When you have found that a sturdy old man is associating with a fierce young one, and is getting down to friendship and hand-shaking, then instead of a bitter enemy, he will become a wholesome friend, through whom undefeated bullies will be driven out of their home in four hours (as I have seen occur), and beasts of seven names and the remaining horde of lesser ones will, by a great miracle, abandon their long-used refuge. And if the dark image of Janus[345] is linked to the fierce youth, it will make a person happy. And these are the greatest feats that art can offer, and nothing else is to be desired except what we have not yet experienced: that the ether should be brought to perfection.[346]

But in the selection of simple medicaments, considerable care is required. I pass over eroded or spoilt or ancient ones; I am now referring to appropriate substance. For instance, in the case of oil and any other fatty medicament, the top part is to be chosen; all fat is &1103 by its nature light and pure, and what is on top is lighter and purer, and so fatter too. Thus the best wine is approved for its strength: what is in the middle is stronger, as what is on top is spoiled by air and by the vessel; what is at the bottom, by the vessel and by the sediment; so the best is in the middle. It is the bottom portion of honey that is approved, because it wins praise for its sweetness. Again, it is sweetest because it is the densest; the densest is the heaviest, and the heaviest in liquids always sits at the bottom. So pure honey, the best, lies at the bottom of the vessel. This was a discovery of long

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[344] Greek physician to the Emperor Nero in the 1st century A.D., originally from Crete, who devised the formula for theriac that Galen mainly endorsed (on theriac, see n. at 193 [1560] in Book II). Burton (*Anatomy of Melancholy*, Part 2, sect. 4, memb. 1, subs. 5 [571]) notes that "Cardan taxeth Galen for presuming out of his ambition to correct Theriacum Andromachi." The remainder of this paragraph appears first in 1554.

[345] The Roman god of doors, gateways, and beginnings. Ficino, the Renaissance Platonist, held that the soul "conforms on the one hand to divine things, on the other to transitory things, and turns with its affection toward both." In reference to this double direction, he occasionally compares the soul to the head of Janus which faces in two opposite directions (P.O. Kristeller, *The Philosophy of Marsilio Ficino* [New York: Columbia University Press, 1943], 197).

[346] "ut aether absolvatur."

ago, and one recounted by Macrobius;[347] but physicians abound in such discoveries, even to surfeit.

Of medical interventions[348] the pushing down of cataracts in the eye is the most subtle, and the extraction of a stone from the bladder; if you deviate a trifle, instead of light, blindness is waiting, and instead of health, death — all the good and bad of mortals hangs by so thin a thread. But this is the practice and the rule for all human affairs: that if anyone thinks straight about them, he will worry less about [631]death, since it is inevitable for us all, and he will take greater care about life. These issues are dealt with in detail in the book *De fato*.[349]

But since everything's conclusions and beginnings are hidden, no wise man can see any true happiness among mortals, nor anything worthy of admiration in such a mass; everything is like a dream, one or more things that give us pleasure or afflict us with brief yet empty grief.[350] This is how things are, even when an oracle is speaking; but let us leave everyone his view, and allow them to be fortunate in a groundless conviction. But this they will not deny, that at least their greatest experiences, these huge pieces of good fortune, spring from tiny beginnings, and this is why anyone among mortals who wants to appear fortunate &1104 not only should notice small details — he must do so.

The most subtle among technical achievements is the theory of burning things, while among studies[351] it is the knowledge of pulses.[352] But there are also other topics in other fields that are attractive and worth respect: for instance, in the nature and location of clouds; it is certain that all clouds are flat, both because they are of that sort and are seen on mountains, and because they are carried straight along by winds; anything spherical[353] if carried along straight is bent inward and broken up — also because there is no cause that can bring about this roundedness.

So let a cloud be GD, and the eye be H, a point vertically above the eye be A; as because of the distance HK, DK is very small because of

[347] Macrobius, *Saturnalia* 7. 8, 13–14 (ed. J. Willis [Leipzig: Teubner, 1970], 7. 12. 8, 13–14 [438–39]).

[348] "actionibus."

[349] Cardano's *On Fate* was written in 1533 and "almost certainly destroyed after 1570" (Maclean, *De libris propriis*, M16 [53]).

[350] "Sed cùm fines, et initia cunctorum lateant, nullam veram felicitatem inter mortales, nihilque dignum admiratione in tanta mole sapienti videri debet, sed omnia quasi insomnium unum, aut plura quae delectant, aut tristitia brevi, sed tamen inani, nos afficiunt." The syntax and punctuation appear to have melted before Cardano's depth of feeling.

[351] "contemplationes."

[352] Galen evidently regarded pulses (of the vascular system) as of much importance; eight treatises upon them are attributed to him.

[353] "orbiculatus."

the angle DHK, and the small ratio which it obtains towards HD and HK, AD will come to seem to touch the earth at K; on the same basis, BL and CM will seem smaller than AH, so ABCD and AEFG will seem portions of circular lines touching the earth at G and D. The cloud itself will look higher at A than in another part, gradually splitting open, and like the internal surface and part of a sphere or bell, in the way that the point A will[354] appear to be furthest from the earth. And so a cloud seems higher up above one's head, and then gradually bending down to earth, as it always looks to onlookers. Furthermore, since this happens everywhere at the same time, it is clear that the cloud is not round, but flat. And so, when DK is not visible, &1105 the cloud at that part apparently touches the earth. This comes about when HD and HK contain DK sixty times over,[355] but as DK is equal to AH, it never reaches 2000 paces; so neither a cloud nor showers appears further than 120,000 paces away, and more truly and accurately, not more than 100,000 paces. On this basis, no one at Milan will say that it has rained in France. Since as a rule, and especially when it is raining, clouds do not rise to five hundred paces, we can rarely see a shower further away than 30,000 paces.

For the same reason, the fires[356] that come down through heaven look highest when they are above us; when they are rising or setting, they seem to stick to the earth—not because they are coming down or rising—rather, they are carried along straight, parallel to the plane of the earth and the horizon, but the change in how they appear brings it about that they look lower down, the further away they are.

There are also products of subtlety in words, accent, and speech. Among words, "Zephyrus" has a sweet sound in three ways: first because it has "Z," secondly "Y," which Latin does not have. Latin has nothing so smooth, and Greek has nothing else. The third way is the meaning, which conveys a very soft wind we call Favonius, which is interpreted as very pleasing.

Accents too are evidence of vast subtlety, since they can distinguish race from race, and then in the same race, town from town, and village from village, and in the same town (unbelievable!) individual districts. You can see the vast powers of voices: by two syllables, kingdoms collapse or are preserved, the innocent are killed, the guilty &1106 escape, all human disaster and happiness are here. In single combat, a little word unwisely blurted out endows the opponent with the choice and the victory, but its utterer with death and abuse. In an embassy, arrogance, rashness, a word carelessly uttered, brings about so many wars, slaughters and riots; it overthrows kingdoms, and lays regions waste.

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[354] Reading "videbitur" with 1554, not the "videbatur" of 1560.

[355] I.e. DK subtends nearly 1° at the eye; it seems that Cardano takes this as some limit of visibility, though under ideal conditions the human eye can distinguish much smaller items than this.

[356] Meteors.

So subtlety is in command in everything, and its power is felt by kings, provinces, cities, villages, and individual homes. And so good judgment is more essential in ambassadors than in military leaders; the latter usually explain how to choose the lesser among evils, but the former can prevent the evils happening. A leader's rashness, however, is more destructive, since its outcome is closer at hand.

Affected speech is irritating: what flows spontaneously is very pleasing—in these features, while art is actually imitating nature, it escapes from the suspicion of art, and flows more fluently. There are seven ways of subtlety in oratory, and among them single ones that make it more obscure. The first way in the grouping[357] is the grammatical: metuo, me tuo, me tu o. The second is the sophistical, for instance, I am telling a lie. The third is mathematical, and is threefold: either combined, for instance, which point in a circle is closer to the circumference; or from the assumptions, as whether the assumptions in the proof by Archimedes by helices make things plain about the straight line equal to the circumference of a circle; or from what has been proved, as whether a general rule for a cube equal to things and to a number can exist. The fourth is physical, and is double: from the thing, and from the cause. From the thing: whether new species of things are provided in individual seasons. &1107 From the cause, whether the movement of heaven follows eccentric circles. The fifth consists in the uninterrupted continuity of speech, as in the little book on the *Immortality of the Soul*,[358] when we gradually draw a person along from one thing to another. The sixth is from the passage from kind[359] to kind, as when we explain drawing up water with a screw, because while the empty lower part rotates, it is filled up.[360] The seventh is from law: the man who has not secured half the votes is not to be freed, the man who has not obtained two shares[361] of the votes is not to be condemned. But since the cases of many of the rest would stay undecided, by another law they are judged as freed or condemned according as each of them was closer to the number of votes. There are twelve judges: someone is condemned by seven and acquitted by five. [632]If eight had condemned him, he would be punished; if six had acquitted him, he would be freed—with five acquitting, and seven condemning, he is geometrically condemned, but freed in accord with a special prerogative,[362] which favours the acquitters; arithmetically his case will be undecided. There are many

[357] "divisio."

[358] Published in 1545; for details see Maclean, *De libris propriis*, M55 (73–74). Examination of its contents of this "little book" (some 79 folio pages) has not revealed the source of this remark, which may possibly refer to the structure of the whole work.

[359] "genus."

[360] See Book I at 45 (1560).

[361] "partes": thirds, presumably.

[362] "privilegium."

other modes of this kind, which for the sake of brevity I intend to pass by, since they can be worked out from what precedes.

Let us revert to natural questions, which are more congenial to enquire into: why is urine among all the liquids more bright at a distance than close up, and the contrary applies to the others?—this makes it easy to recognise. Urine contains fatty moistness, which screens it[363] when close up, but illuminates it from a distance, because it possesses a fiery light. The other liquids have no screen, because they are pure; or if they are not, what is impure screens the whole, hence &1108 the further away they are, as I have said elsewhere, the darker they are. And urine is of very thin substance because of its heat, so much so that though it is salty, it still turns out lighter than water, but not all of it. This is why urine is good for inflation of the belly, and much more so than salty water; by its thinness it penetrates into the inside, and carries along with it the power of salt, which disperses the flatus, and strengthens the bowels. Thinning out occurs through heat; this is why fresh warm urine is chosen, from an unpolluted boy (it is the hottest, through sex and age).[364] It is a property of urine (not of all of it, but of it almost alone among all the liquids) to turn cloudy. Wine too turns cloudy; it does not return to become normal wine, but with the heat of a fire urine gets clear. In my view, there is nothing like it but olive oil; while it is liquid, it is also clear, but when it congeals, it is not clear at all. Fat is therefore the reason for the cloudiness, which is why very dry urines never alter.

When through the huge heat the humours and blood and fat liquefy in fevers, cloudy urines occur; if they do not settle, they do not clear. If then they settle, there is hope, because what makes the cloudiness is earthy; if not, not—it it fatty. However, much is also overcome by sturdy powers with the passage of time. Urine that does not turn cloudy is devoid of fatty juice. So cloudiness is not a corruption of the substance, but a coagulation of the fat. This is why, if much humour settles while urines were clouding, it is moist earthiness, but if not, watery and airy.

But someone will say, "If what coagulates was already in the urine, why did it not make it cloudy from the start?"—for it is evident that &1109 the whole of the urine gets cloudy. So how could portions coagulate, but not be diminished?—things that coagulate contract, and while they are being attached to other things, the original ones must withdraw. It appears that oil does not just fail to diminish, but actually increases while coagulating. So while the fatty part in the moist wateriness coagulates, the quite thin liquid is converted into air, and increases, which makes the rest get condensed and cloudy. Hence in all cloudy oil, and urine too, coldness requires that very many parts be transparent, and

[363] Translating "adumbrat" with 1550 and 1554, not the "ad umbra" of 1560. The sentence is modified at other points too.

[364] The remainder of this paragraph with the two subsequent paragraphs first appear in 1554.

more so than before they were cloudy, yet with clots closely intervening, the whole looks cloudy. The earthy part in urines is thin and not free of heat.

Waters that are spontaneously hot are quite like urine. Among them those that contain sulphur and alum, or salt or asphalt, are quite cloudy, since they are mingled by external heat; but those that contain iron or silver or copper are clear—through nature doing the mixing, they get like that from the waste stuff of metals. Technique cannot imitate these, but can imitate the previous ones.

There is in fact the celebrated celestial heat, which really mixes, as has often been mentioned, and it makes something that is like itself, because it has it in potentiality. Heaven's heat is in what contains a human being in potentiality, but it procreates a human being in actuality; but that natural heat of ours makes in potentiality the kind of thing it is contained in—for example, a human being does not generate a human being abruptly and without intermediate; no, semen does it, &1110 because it is a human being in potentiality, since it is shed by a man himself during his life.

But as there is a difference, so there is a likeness, and deep consideration is needed in exploring it. Stars there—gems here; intellect there, and substances in motion—animals here, of diverse sorts; varied substance of bodies there, and a degree of density[365]—here a very great variety of earth and water and air; miracles there, and numerous portents, such as lines of battle, or swords—here, double-headed progeny, hairy infants with teeth; there, some substances linked to bodies, as plants and metallics are here; perpetual motions there—rotations of water here; light and illumination there—and here too. To rival what is above, nature has fashioned in the universe as many and as great things as there were there, according to their kinds and species and accidents. Nature's own power is in them, but more apparent in mortals.

But since some things seem occult, they have a very apparent reason[366] to operate on a concealed pattern;[367] for instance, why is it that since veal is moister, it is juicier and fattier than beef?—as Galen too bears witness; but the juice from beef is succulent and fat, and from veal is dull and tasteless. The reason is that in beef this fat is more compact than in veal, and hence it releases vapour[368] very little in response to fire, and makes water fatty. Why does butter sometimes prevent water from boiling? Is it because being compact, airy and fatty, it attracts to itself the vapours which make water boil? Why does potters' clay attract impurities? As it is tenacious, heat does not disperse it, but compacts it. And so when they boil, they are mixed, and &1111 straw and dust and earth and everything like that stick to it. Why does walnut make chickens cook faster? Does it make

[365] "spissitudo."
[366] "causa."
[367] "ratio."
[368] "exhalat."

the air and heat penetrate, because it has a pungent virtue, in the way that was mentioned earlier about mustard?[369]

On the same line of thought:[370] why could balsam only be watered from a particular well that was close to the Nile? Was this because everything that is nourished resembles its nutriment? And so Nile water is very thin, and of airy substance. This same water, permeated with a particular kind of pitch, can nourish balsam bushes, and no other can do so, unless it is like it. Similarly, people [633]say that "anthropophagi" (called Caribs by some people, Cannibals by others) are of an appearance so aggressive, grim and terrifying, and pitiless too, that the rest of humanity can hardly bear the sight of them even as captives or as corpses; reputable authors report the same about Marius seven times consul, when a captive,[371] and about Nero when dead.[372] Food, then, alters the appearance and nature; this was proved excellently in the second book of *Contradicentium Medicorum*.[373] So by practice, and the type of feeding, it is easy to change the habits and form of animate creatures, and also to attach marvellous properties to them.

Some conditions have their cause out in the open: for instance, why people who have one eye that sees badly or not at all from childhood turn out squinting. The reason is very obvious: when an eye does not see from the opposite side, it is forced to turn in and twist, and from habit they turn out squinting.[374] They have eyes tilted towards their nose and[375] looking back. But if blindness comes on after infancy, they do not &1112 squint so much, for two reasons: one is that already the eye is accustomed to stay in its own position and not be deflected; then, the nerves are already hard, and do not readily do duty for new movements; the remaining reason is that adults deliberately bend their neck instead of their eye.

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[369] See Book VII at 448 (1560); but all that is said there is that it is a cause of dreams.

[370] "ratio."

[371] For instance Plutarch (*Life of Caius Marius*, 39; Loeb 9: 573): "Now that part of the room where Marius happened to be lying had not a very good light, but was gloomy, and we are told that to the soldier [sent in to kill him] the eyes of Marius seemed to shoot out a strong flame, and that a loud voice issued from the shadows saying: 'Man, dost thou dare to slay Caius Marius?' At once then the Barbarian fled from the room, threw down his sword on the ground, and dashed out of doors, with this one cry: 'I cannot kill Caius Marius.'"

[372] He was smelly and unkempt in life (Suetonius, *Nero*, 51) but I have not identified a similar statement about his corpse.

[373] See n. to 158 (1560) in Book II.

[374] Jean Fernel (see n. at 193 end [1560] in Book II) does not seem particularly helpful here, though in his *Pathologia* (Bk V, cap. 5, 271) he does say that squint prevents the two eyes sharing one view.

[375] Perhaps Cardano meant to write "or" here.

But on the other hand, a very subtle study arises from this, which Galen admits he does not know how to resolve:[376] the way in which muscles are moved; uneducated people and children and beasts move them appropriately, and for the actions they intend, though they are not acquainted with their functioning, indeed are unaware they have muscles. And so, since there are two requirements for appropriate movement (the choice of the part,[377] and of the muscles in the part), we must reckon that it stems from the soul and spirit, and the remainder from habit; if you see children trying to walk, they pull all their muscles, now this one, now that, and finally get used to shortening the appropriate muscle for each movement. This is clearly visible in those who strum a lyre: they are guided by practice alone to pluck the strings on each side at the right time.

But I feel there is a greater problem with the parts of the body, since in order to speak, people move their tongue, not their hands, and beasts move their legs to walk, not their head. However, this too is seen to occur from the same cause: when you throw a newborn puppy into water, it moves all its parts; in fact, it feels itself less suffocated with its head extended, and better supported with the front legs in motion; through the capacity[378] which the Greeks call &c1113 "phantasia,"[379] it keeps its head steady above water so far as it can, then it moves its tail, then its back legs more, and most of all its front legs; but it does not feel this helps it, it stops moving them, till in the end it adjusts to appropriate movements. It is evident that one animal swims better than another, according to their natural willingness to learn, and the adult does it better than the newborn, and the experienced animal better than one that has never swum. And it happens like this in other movements too.

So all these movements depend on two principles: the first, that every animal also has a capacity, even if an incomplete one, through which it pursues what gives it pleasure, and departs from what harms it; what remains is a kind of memory or disposition, by which it has learnt to move parts and muscles—which parts and which muscles suit that movement it has already discovered elsewhere; and for that reason we see some men compelled through long illness to learn again how to walk, like infants. So their muscles and parts have learnt through practice to be operated at the appropriate moment. Of all the arts, the more subtle ones are those that explain how to carry out divination, for as I said, to find out the future is almost divine.

The more important arts here, besides those that consider the nature of the seasons, as we said before, are Astrology, and the theory of pulses; these alone

[376] In his *De motu musculorum* (II. 6; K. 4: 444 onwards) Galen is puzzled whether respiratory movements and movements in sleep are or are not voluntary, but is not addressing exactly the point next raised by Cardano here.

[377] "membrum."

[378] "virtus."

[379] I.e. imagination.

nearly achieve their goal. In the case of an invalid, through its[380] help, the physician actually sees death standing far off. Thus a wise man is really much more blessed than a king; for when the wise man recalls to himself what he knows, and appreciates how far he is from common society, he will live safe and sure, and hence &1114 contented. But when a king recognises the trials, the slavery, the risks, and all he is soon going to lose, he will live in uncertainty and anxiety, trembling with fear at every turn. So this is the utmost happiness that God could or would allot to man. He would allot whatever he could, in the case of good people; when the rest lies in uncertainty, the soul[381] itself, being of the thinnest substance, thus has an abundant share of immortality, and of a better life of some sort than could be had amid squalor.

To reach this wisdom, a delight in studies is needed. We will attack Euclid first, then Al-Kindi,[382] so as to reinforce our capacity for imagination,[383] and then the Calculator;[384] imagination is reinforced when freed from every sense. Afterwards, Arithmetic should be learnt, and among our own writings, in the books of the *Ars magna*,[385] and the gardens of numbers.[386] Then we will move to Archimedes,[387] Apollonius,[388] and Eutocius.[389] Then to Scotus[390] with Aristotle and his interpreters, Theophrastus,[391] and Alexander,[392] then Themistius,[393] Simplicius,[394] Philoponus,[395] Averrhoes,[396] and the classical heroes of this kind.

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380 "illius"; it is not evident what this word signifies here—perhaps Astrology.

381 "animus."

382 Al-Kindi was probably born late in the eighth century at al-Kufa, and died about 866 or 873. See Book XVI at 1012 (1560), where he is named "Alchindus." One of the very first Islamic philosophers, he wrote on the theory of vision, among other topics. See for references Lindberg, *Theories of Vision*, 221–2, n. 1.

383 φαντασία.

384 On the Calculator see n. in Book XVI at 1010 (1560).

385 See n. in Book XVI at 978 (1560).

386 "hortis numerorum." The meaning is unclear, and no work of Cardano's bears a title resembling this.

387 On Archimedes see n. to Book I at 45 (1560) .

388 On Apollonius see n. in Book XVI at 96 (1560).

389 On Eutocius see n. in Book XVI at 1012 (1560).

390 On Scotus see n. in Book XVI at 1010 (1560) .

391 See n. in Book V at 373 (1560).

392 Alexander of Aphrodisias, who flourished in the early 3rd century A.D., was a Peripatetic philosopher and commentator on Aristotle. Details in *OCD*.

393 Greek philosopher of the fourth century A.D. Details in *OCD*.

394 See n. at 361 (1560) in Book V.

395 Philoponus (ca. 490–570 A.D.) was a Christian commentator on Aristotle; details in *OCD* and *ODMA* 3: 909.

396 Averroes, one of the most famous of the mediaeval Islamic philosophers, was born in Córdoba, Southern Spain, a judge successively at Córdoba, Seville, and in Morocco,

We will place Ptolemy in the sixth place, and in the seventh Vitruvius. From here we will move to the art we choose to profess: medicine, or jurisprudence, or Theology. And this is the order of the branches of knowledge.

In the individual branches, one should read all the best authors, after all (as all wise men agree), "Our life is short."[397] Who those authors are has already been &1115 mentioned in part; as a rule, no one should be esteemed in some art who has not written a good deal, apart from in Poetry and Mathematics; as the rest of the arts consist in judgment apart from discovery, judgment starts from the knowledge of many things; if love of glory drives people on, and a pen is available, those who know a lot, and know it very well, must write a lot; glory is indeed a sweet pleasure, and the eternity of one's name and of the image of one's own intellect, and far preferable to the statues and pictures by which kings look after their own memory. For [634]what difference is there between this present writing and my own intellect?—the intellect is mine, it is whatever there is good in me. So anyone who reads this after two thousand years will see my intellect, and appreciate it. And this is the permanence of each person's intellect, but not its eternity. So after one's allotted span, what is best in us remains, even beyond what one has written, and the ages will hear me speaking; thus from a mortal person something is generated that remains forever—the understanding and what is understood are one, and an eternal substance. And this has been dealt with elsewhere.

However, in poetry a person who writes little can command esteem, being stirred by ecstasy.[398] And in mathematics, because only what has a conclusion and what is required for proving the conclusion are favourably regarded—when even though Euclid and Archimedes knew much more than they wrote down, more praise and commendation are given in these fields to those who wrote more (like Homer, &1116 Vergil, Ovid, Archimedes, Euclid, Ptolemy) than those who wrote little (like Theocritus,[399] Persius,[400] Catullus[401] or Nicomachus,[402] Diocles,[403] and Architas).[404]

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in 1182 he became court physician to Caliph Abu Yusuf, but in 1185 was banished. His *Commentaries on Aristotle* were his most important works.

[397] This is the opening of the celebrated first *Aphorism* of Hippocrates: "Life is short, but the Art (of medicine) is long."

[398] "furor."

[399] Theocritus was a pastoral Greek poet of the early third century B.C.

[400] Aulus Persius Flaccus (A.D. 34–62) was a Stoic satirist who wrote in Latin in the age of Nero.

[401] Latin poet of the first century B.C.

[402] Probably Nicomachus of Gerasa, arithmetician and Neopythagorean philosopher who flourished about A.D. 50 to 150.

[403] This Diocles is probably a mathematician of about 200 B.C., who wrote on conic sections and whose work is only preserved partially in citations in Eutocius.

[404] On Archytas of Tarentum see n. to Book XVI at 986 (1560).

Theon,[405] who expounded the *Elements* of Euclid and the great work of Ptolemy,[406] should now be replaced among celebrated authors. Among other discoveries, he proved that the sphere was the most capacious of all bodies. Reasoning shows this, and we also realise its truth from craftsmanship; we realise, even if not precisely, the sort of ratio the sphere's capacity bears to that of the other bodies. Thus if a cube's side is four, its body volume will be 64, and the area of all its six surfaces 96; but a sphere, whose surface is 96, has according to Archimedes a greater circle[407] of exactly 24; hence its diameter will be, from Archimedes, almost five and a half,[408] since the area is 24. Therefore a cylinder whose base is this greater circle will be, so to speak, 132;[409] it is in fact made from the diameter multiplied by the base. But a cylinder on the greatest circle of the sphere is from Archimedes one and a half times the sphere; so when the cylinder is 132, the sphere will be about 88. So when the cube's surface area is 96, the solid cube's volume is 64, and when the sphere's area is 96, the solid sphere's volume is 88.[410] So the ratio of a sphere to a cube, when their surface area is equal, will be extremely close to 11 to 8.[411] This is more readily demonstrated on a plane; we have explained on a definite basis in our books *On the Variety of Things*[412] all solid bodies that can be included in a sphere, so far as they can be drawn on a plane.

Now the proposition is to fashion a sphere with slight labour and a small error &1117 from its surface area; whether we wish to fashion a celestial or an earthly one, the following will be very convenient for the typographer's technique. Let us propose a sphere whose equatorial circle is 44, and divide it into twelve equal parts by six great circles drawn through the poles; and let those twelve zones be separated; I say that they can be projected[413] on a plane without distortion.[414] Hence let there be a mutual transfer from solid to plane and from plane back to solid, without error worth mention, so that what was found on a

[405] Theon of Alexandria was a mathematician in the fourth century A.D. who commented on Ptolemy's work and effectively transmitted his works to Islamic science.

[406] Ptolemy's major work was the *Almagest*, a complete account of astronomy as the Greeks understood it.

[407] The area of the circle whose diameter is the sphere's diameter.

[408] More precisely, 5.528

[409] Reading "cxxxii" with 1550 and 1554, not the "122" of 1560. This is very close to the volume of a cylinder circumscribed round the specified sphere.

[410] More precisely, about 88.45.

[411] Sphere area = $4\pi r^2$ = cube area = $6s^2$. Hence $r^2/s^2 = 3/2\pi$ and $r^3/s^3=(3/2\pi)^{1.5}$ and sphere volume $(4/3)\ \pi r^3$ divided by cube volume s^3 =1.382 approx., while 11/8 =1.375, a difference of about 0.5%. The material from here to the top of 1118 (1560) first appears in 1554.

[412] *De Varietate Rerum*. On this work see n. at 93 (1560) in Book II.

[413] "extendi."

[414] "ut non laedantur."

solid basis could be fashioned on a plane, and when fashioned on a plane, be reduced to a solid; if there is any difference, it will be largest in the middle.

The portion has 3 2/3 out of 44 in the sphere.[415] So its sine is a fourth part of the diameter,[416] that is, 3 ½ squared becomes 12 ¼,[417] and just needs to be produced from 14 (the diameter) divided in two.[418] So the parts[419] will be about 13 1/16 to 15/16, so this is the sagitta.[420] So the sine squared and joined to the sagitta squared are 13 33/256. So the chord subtended by an arc of 3 2/3 units differs little from 3 5/8.[421] So the difference between the arc (3 2/3) and its straight line (3 5/8) is 1/24. Hence 1/88 is quite undetectable in relation to the intercepted part of the equator.[422]

And this relation[423] is to be followed in all parallel zones,[424] as is evident from what we have shown in the seventh book on Euclid, and it will be less obvious when on a small scale.[425] Consequently it makes no difference whether it is extended on paper or on papyrus. And in this way the senses can grasp the ratio of the sphere to all the other bodies which have an equal total area. In fact, as already mentioned, the sphere's shape is &1118 rounded, and contains more, thus everything, so to speak, has a sort of sense:[426] the more it holds, the more resistant it grows. And so the liquid elements, especially air and water, and less

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[415] So each of the twelve segments of the sphere occupies one twelfth of the great circle which is 44 long, i.e. occupies 44/12 = 3 2/3. I am indebted to Dr Jackie Stedall for unravelling the following passage for me.

[416] The sine of 30^0 is half the radius, i.e. 3 1/2.

[417] That is, "3 ½ squared becomes 12 ¼." 3.5 squared is 12.25; and Cardano is now calculating the cosine by Pythagoras.

[418] That is, the square of the cosine length is 7 squared minus 3 ½ squared, or 36 ¾; and the cosine length is very close to 6 1/16.

[419] I.e. the ratio of rest of *diameter* to sagitta.

[420] The sagitta or "arrow" here is the portion of the radius at the midpoint of the segment outside where the chord across the segment intersects it, which is in fact 15/16 long in the present case.

[421] This is true: the chord corresponding to an arc 3 2/3 long is very close to 3.625 long; I make it 3.624.

[422] The arc is the "true" dimension of the curved surface; the chord is its projection, and so the projection is very accurate in length.

[423] "ratio."

[424] "parallelis"; see Pliny (*Nat. Hist.* 6. 212; Loeb 2: 495). Pliny in fact specifies 7 zones plus 3 most northerly ones not covered by the ancients, starting with zone 1: Arabia, and working west through Carthage to the Pillars of Hercules and ending with zone 10: starting in Scythia and ending in Thule. Then a further 2 more southerly ones added still later, moving as far south as Syene in Egypt.

[425] "in parvis quoque."

[426] "omnia quasi quendam habent sensum."

clearly earth,[427] of themselves adopt a rounded shape, that being the most secure against damage from outside.

In addition to this latent sense, living things themselves possess other faculties: three main ones—generation, nutrition, growth. Four assisting these: attraction, which arises from great heat and much moistness; retention, which is a sort of mild attraction, as what attracts also retains, and so is attracted by greater heat, and that heat has no need of moistness. If the heat is small, and moistness is plentiful, it is driven out; but when the heat and moistness are very large, it is concocted. Therefore very great heat is either accompanied by very great moistness, and concocts—or with medium moistness, and attracts; medium heat with much moistness expels, and without moistness retains.

There are also three kinds of causes, of three virtues in animals apart from these causes; while there are those that retain, attract, or expel, those that concoct cannot come into being from villi or fibres; they also come into being from muscles obeying the will; thirdly, events occur from a vacuum, as in the case of the heart. This has been dealt with elsewhere.

There is evidence in plants of the expulsive cause, and an instance can be taken from their drops of sap;[428] they appear to detest what they expel, and avoid it as far as they can. As they do not possess the wherewithal to escape,[429] they do expelling instead. But some kinds of animal, like cranes &1119 and swallows, come to us in spring, fleeing from the sweltering region—in autumn, afraid of the winter, they migrate in flocks to the warm regions, and so are seen in Alexandria.

It would take forever if I wished to cover the wonderful discoveries of every technique.[430] I have noticed people jumping much further from a high spot, and wanted to discover the theory of this. So assume a plane AB; let the jump take

place in the plane from A to C; let there be a wall erected on the plane AD; I say that from D the jumper will [635]jump beyond AC, and less than twice AC; I say the same about throwing a stone, because at first it travels along the circumference of a circle, so to speak parallel to AC; the impetus cannot operate beyond twice its strength, so it travels along a circumference equal to the first one; this subtends the lesser curve AC,[431] so will not be capable of transfer beyond C, over an interval the size of AC, which was to be proved. If then AD should be much greater than AC, there will be a point E of the jump virtually distant less than twice as far as CA from the point

[427] 1550 and 1554 include fire too; but it is excluded from the list of elements in the discussion of Book II, at 78 (1560) and subsequently.

[428] "lachrymae."

[429] "instrumenta ad fugam apta."

[430] "ars."

[431] "sinum minorem AC"—might alternatively mean "a lesser curve than AC."

A, indeed less than through DA and AC linked, and more than the line through DC.[432]

A similar question is, why as we climb up do our legs get so tired, and a person pants quite fast? The difference between a climb and the flat is not trivial; indeed, someone is more distressed by climbing 500 paces up than by 4000 on the flat. The reason for the hard work in climbing through upward slopes is threefold: &1120 the first is a reason common to all motion, since the muscles and all the limbs get moved. The second, one that applies also to climbing up ladders too, is that one is forced to raise one's body by a height as great as one's step; the body is heavy, and laboriously raising it is a heavy task too. It is true that on the flat too the body is raised for a while, but so little that it is barely detectable. Hence the higher the steps of ladders, the more tiring it is to climb up them. The third reason is a particular one for a sloping situation; since no one can rest properly except on feet flat on the ground, and the surface of a slope is not equidistant from the earth's centre, one is forced, both while climbing and while standing still, to maintain oneself with a considerable effort, since the soles of the feet are not at rest. So one is forced to do one of three things: either to stand just on the front part of one's feet, or to bend one's whole body forward, or maintain oneself with great muscular stretching, a very taxing task.

Consequently what is reckoned the greatest test of strength is to climb slopes with one's body upright and one's feet flat on the ground. It is evident that as the slope gets steeper, it gets much more difficult, and a steady rhythm is not maintained. So considerations such as these arise in relation to professional skill[433] and involve wonderful subtlety, but in subtlety no other professional skill can be compared with that of joking,[434] much less that of magic. Hence it is now time to deal with the causes of marvels.

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[432] Material from here to the start of the final two sentences of this book appears first in 1554.

[433] "ars."

[434] "iocularia."

[635] &1121 Book XVIII
On Marvels, and the Way to Represent Diverse Things Beyond Belief

I recall that when the most blest Emperor Charles V[1] had come to Milan, when the Prince was Franciscus Sforza,[2] the second of that name, there was in the Emperor's retinue a Spaniard named Damautus[3] or Dalmagus, who worked such marvels and dazzled the eyes of the onlookers so neatly that those who had no Philosophy took him for a magician—and not, I gathered, the sort that has been seen in our own time or in much older times, because he used to perform unheard-of and incredible feats.[4] Recently I became aware of Franciscus Soma[5] of Naples, a noble young man, who is thought to be barely reaching his twenty-second year; in addition to an unusual acquaintance with the art of music, so that he also has no peer in plucking the harp,[6] he is competent in many tricks beyond belief. Among the other tricks that I and other friends of mine often saw, and whose natural explanation I could never work out, he used to perform the

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[1] This Holy Roman Emperor reigned from 1519 to 1557.

[2] The *first* of that name (1401–1466) was a notable condottiero for whose military career full details are available at http://www.condottieridiventura.it/condottieri/s/1836%20%20%20%20%20%20FRANCESCO%20SFORZA.htm. He was Duke of Milan from 1450–1466 and founded a dynasty. A later member of the dynasty, also named Francesco, was Duke until he died in 1535; Charles V then took over his role and Spain then dominated Milan for 170 years.

[3] A "magician" of this name (the name first appears in 1554) in the retinue of Charles V is recorded as having in his repertoire "Feuerschlucken, Ausspeien von Flüssigkeiten, Durchstechen der Glieder, Verkettung eiserner Ringe, Knabe ohne Kopf" (fire-swallowing, spewing out of liquids, limb-piercing, linking of iron rings, headless boy); see http://www.mzleipzig.de/hokus-art/html/personen/damautus.htm#DAMAUTUS; accessed on 9 Nov. 2006.

[4] The remainder of this paragraph first appears in 1560.

[5] Not traced.

[6] "lyra."

following: he would scatter cards[7] on a table, in such a way that the pack could not be broken up, and ask us to pick one and hide it; then taking over the pack, he would shuffle them and predict which the one removed was; but this could perhaps be put down to sleight of hand— however, what follows could not: with the card inserted once more in the pack, and the pack put down, he would ask &1122 [wrongly numbered 1022] one or other of us to pick a card; we recognised that the first person who had taken one out had always taken out the same one, as if he had made us always take the same one, or had altered the face of the thing.[8] And as I had brought along a cunning and discriminating[9] man to the show, he admitted that he could not follow how this could be done; although he did not think that was a reason to accept that there is some power in this lower world[10] in addition to the power we see imparted to things by nature. And so this trickster used to defeat all our care, and he overcame cunning. He used to mumble something all the time while he was at his business, as if he were doing sums, although it was certain that the explanation did not reside in numbers. Furthermore, when an associate of ours had a look at the card he had taken out before he placed it on the book,[11] Soma said, "You have muddled everything up, and ruined my scheme. However, the card is the same one that you had removed previously—twin flowers—and we can make out that it is." And though he has shown me some more wonderful feats, the evidence was that it [636]all was the work of a conjurer rather than that of demons, or much less was it miraculous. However, it was too extraordinary for us to follow by human deliberation. And unless he had sometimes asked us to take out a number of different cards, I would have suspected that he had supplied a pack consisting of cards of the same kind, for instance all of twin flowers; this trick would enable anyone who took out a card to seem always to come on the same one. But (as I said) the &1123 [wrongly numbered 1023] diversity of those that were left was a barrier to this theory.

Whatever the trick may be, I recall reading that this technique and conjuring had been imported from the New World, where there are extraordinary practitioners of them. It is certain that the authors of antiquity were not acquainted with them and did not reverence them, as is recorded in relation to Pharaoh[12]

[7] "chartas."

[8] "rei," presumably the card.

[9] "Epicureus": one of a number of facets of Epicureanism in antiquity was criticism of the judgments made from sense perceptions; the perceptions were in the Epicurean view never wrong, but the judgments might be (*OCD*).

[10] "in his inferioribus."

[11] "libro"; the word for "pack" earlier appears to be "cumulus."

[12] The reference is to Pharaoh and his Egyptian magicians, with Moses' countermagic (recorded in Exodus 6: 1–7, 7: 8–12), together with the famous "Plagues."

and to Simon Magus.[13] And though this skill is so marvellous, it is held to be worth nothing, since a cook out of the ordinary retains some good reputation. As I believe, the reason is manifold: firstly, because it is concerned with useless things; secondly, because it is conducted by people of no standing; thirdly, because they once relied on divine protection, but now it is isolated. In addition, the laws condemn it; and because in the past princes were deceived into false hopes, they became exposed to scorn. Indeed, what good does it do to swallow fire or puff it out?—those who swallow it extinguish it with saliva they gathered previously under their tongue; those who breathe it out wrap it in cotton or tow. These are the portents of daring rather than of talent. There is no end to the inventions of this skill—shifting things, hiding them, swallowing them, emitting floods of fluid from one's eyes or forehead, producing nails and string from one's mouth, chewing glass, piercing one's arms and hands with a spike, uniting iron chains while the links remain intact—indeed, a greater feat, I have seen three rings thrown up and coming down interlinked, though they were unbroken and separate before and while being thrown up. Conjurers show changing forms in one and the same book, with the earlier ones always vanishing. They &1124 bend a sword with their naked belly, pressing it from the tip to the hilt; other people appear to conceal it, and hide it as it makes its way in. They show a child without a head, and the head without the child—but they are all alive, and the child comes to no harm in the meantime. If I were to list how many and how impressive things can be done with small wooden statues (the common people call them "magatelli"),[14] I would run out of daylight. They play, they fight, they hunt, they dance, they blow on the trumpet, they pursue the art of cookery, and all this, though remarkable, is of no use, as I said; and when you have got wise to the system by which they deceive the eye, it comprises various tools made for the purpose, and sleight of hand, and if they wish to teach you, you will not be thought fit to learn as a favour. Only items hidden in the mouth follow a natural plan: they stay hidden behind the uvula[15] in a wide space which lies between the trachea and throat and palate bone; some magicians can even swallow and (when they wish) vomit, aided by prolonged practice.

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[13] In Acts 8: 9–24, a magician called Simon joined the Christian apostles and then sought to purchase for money their ability to work miracles, an attempt of which the apostle Peter strongly disapproved.

[14] Marionettes, dolls.

[15] "Columella"; this is undoubtedly the uvula; "Between them (the tonsils) there hangs down from the end of the palate a rounded piece of flesh which serves as a plectrum to sweeten and regulate the voice; the Greeks call it gargareon . . . but the right name is columella. When it is swollen and inflamed by an access of humour, it gets the name uva [now uvula]." (Fernel, *Physiologia*, trans. Forrester, 99–100)

Other[16] people fake wounds so true to life that they fool surgeons. On the back of their hand they flatten out a lump of a thin mass with lyre strings embedded in it; they split it with a sword down to the skin as far as the cracks in it, and sprinkle with fresh blood—you will be astonished! A Greek friend of ours used to demonstrate many tricks like this, for a fee. Not long ago, one Phratrius, an old man of Mantua, placed an axe he had freshly sharpened on the skin of Petrus Maria Locarnus in the neighbourhood of his spleen, and used an iron club he held in his right hand, weighing twelve pounds, to hit the axe he restrained with his left hand six huge blows (unbelievable!) in a single day—and three on the next day, &1125 and did not cut the skin, but the axe edge left a sort of groove. However, inside in the internal organs wounds that had been inflicted were found, like wrinkles. And this extraordinary man administered an emetic, with which he almost killed the fellow, and his stomach did not become less swollen, nor did his spleen break up. So it is accepted that with the stomach yielding, and the skill of the dealer of the blows, rather than with the wretched mutterings of the victim, the axe did not penetrate in the meantime—perhaps too the edge had been surreptitiously covered with wax. You would believe anything rather than a miracle that is ineffectual: either a spell, or demons, where no sensory illusion but a serious business is going on, or something is being divided or broken, or does not happen though it should, or is shifted—be aware that incarnate demons[17] are more skilled than the actual genuine demons.

But people who consume poisons, and if they often fake doing that, are taking part in a more perilous example, and one that has turned out badly for many people. If there is no room for tricks, itinerant performers fortify themselves against these poisons by consuming a lot of butter beforehand. Other people handle snakes, but they are either harmless, or the fangs have been removed beforehand, or they have been emaciated by hunger, or are sluggish with cold, or trained in the family. Hence they convey only recklessness to other people, without a remedy, and through these examples extraordinarily do harm to simpletons and to children, and expose them to risks—this is why they are rightly called itinerant performers and tricksters and impostors, and considered disreputable. Nowadays too they are punished in some towns, for bringing harm and no benefit. There are people who purport to be stricken by divine inspiration, a thing quite marvellous because of the &1126 steadfastness they have gained for themselves by practice. Others belong to the tribe of actors, or are dancers, and besides being harmless, they give a good deal of pleasure, and are not barred anywhere by laws.

Bolder than these are the so-called rope-walkers. With them there is in fact a component of skill, and more of a natural basis; accordingly, I will start discussing them as if tracing the origin of natural magic from the start. It is in fact

[16] This paragraph and the opening of the next appear first in 1560.

[17] "daemonas carneos"—i.e. in the guise of actual wicked people.

magic, when something extraordinary is done on natural principles, concealed though these are. This then is the principle of the rope-walkers. A bold and trained man walks barefoot on a considerably stretched rope; he holds in his right and left hand a weight of ten or fifteen or even twenty pounds of lead. When he veers to the right, being intent on his job (this is why he should be very daring), he tenses and stretches out his left arm, and slackens and contracts his right one, and so before the right arm outweighs the left by its power, he evens out the weights, and brings his body back into equilibrium, and then gradually restores the weights and his arms to their original condition. This is essential, as before he is about to fall, one side should [637]be heavier than the other one in a definite ratio. As this ratio is gradually attained, before it is attained he tilts by extending and tensing his arm to the other side, and so he does not fall. Thus he can fall if the rope is not precisely stretched, if his limbs are afflicted by numbness in the meantime, and if his body is not held strongly tensed—if he gets frightened, if he tires out, if he lacks skill or practice, &1127 so as to tense too slowly until he tilts, or is too tense, so that he topples to the side opposite to the one he feared. I omit the detail that the weights should follow a definite proportion, or one close to it, to the weight, size, and even strength of individual performers. So if these six conditions are met, he is in no danger. And so there was a boy with wooden balls attached to his feet, and sometimes wholly enclosed in a sack apart from his arms, who used to walk on a rope stretched between the tops of towers, while I worried greatly about the risk to his life.

Another man used to make his way from the lowest floor to a tower,[18] which is extremely difficult, since in this exertion the kidneys have a hard task. The same man used to let himself down from a tower on his front without weights along a rope, with his hands stretched out to the floor; the strength of his hands and arms was so lasting and steady that he used them instead of weights. The same man used to suspend himself from quite a thin rope by his foot, a very wretched business, from the rope when he was very close to a tower—a shocking and frightening sight. With his strong kidneys and back, he used to grasp a shackle, and thus get himself back onto the rope again. They both used to feign falling headlong, and would stick head down to the rope by the end of a foot. You can grasp how much of that sensational strength[19] was needed in the extremity of the foot: they were supported only by the curvature of their toes, and that onto a wooded place.

There was also a boy who used to throw himself headlong with balls, and he used to hang with one of the balls sticking to a rope between the sole of his foot and the ball, I do not know on what basis, so as not to &1128 slip down

[18] "descendebat ab imo solo ad turrim . . .," and the meaning is unclear; normally "descendere" always means to move *downward*.

[19] "illius roboris."

because of its roundness.[20] But the skill and daring of two Turks was beyond all belief and expectation: I refer to what was visible to you and the whole town. They were two young men not big of body, but rounded; first of all each of them used to take a person on their shoulders and go up a rope inclined at forty-five degrees, without the help of weights. Then they attached swords of about three palms in length,[21] very sharp, and razor-edged, to their ankles,[22] and would go up again with the same person, their feet so blown up that it would not be easy to walk even on a flat surface. Then with a plank placed on a rope, and their feet placed on wooden stakes called "scanciae"[23] by our fellow-citizens, he[24] used to walk on the plank thus positioned, as the plank could not of itself stand on top of the rope, even for a moment. Then he would fasten on his feet on each side five round pieces of wood which were transfixed by a fairly thick iron wire[25] and thus stuck together (though in such a way that none could lie straight on another); and with them he would walk on the rope, though on flat ground no one can walk like that, or even stand up, with rounded pieces of wood sliding about no thicker than an arm.

Later on, he used to walk on a rope on small brass plates, not tied on, which he had to hold in place by extending his legs. Next, terrifying to relate, he would sit up in a cauldron (this is what Italians call a large brass vessel), the cauldron hanging above the rope.[26] And what seemed close to a miracle: he pulled a spear with weights under the vessel, so that the cauldron seemed to be hanging in the air; he previously pulled back the spear when it was placed between the vessel and &1129 the rope. He used to dance rhythmically on the rope to the beat of a drum, and throw himself headlong from it, sticking to it at times only by his heel (I saw it with these eyes of mine), and at times by his ankle and the navicular bone[27] of his foot. It would be staggering for anyone to see one of these people standing on quite a thin rope, a sort no thicker than a thumb—and without moving his upper part, shake his lower part along with the rope with such vigour

[20] "Puer etiam praecipitem se dabat cum sphaeris, alteráque earum fune inter pedis plantam, et sphaeram haerente, nescio prorsus qua ratione, ne ob rotunditatem dilaberetur pendebat." Syntax and consequently meaning not entirely clear. The remainder of this paragraph along with the next three and the opening words of the subsequent one first appear in 1554.

[21] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

[22] "pedum malleolis."

[23] "scansie" are "shelves" now in Italian.

[24] The word is singular, not plural.

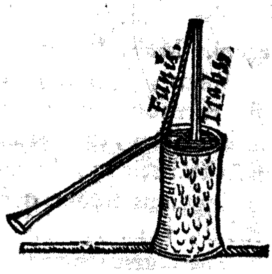
[25] "filum."

[26] ". . . in caldario . . . sedens stabat, caldarium supra funem pendulum, horribile dictu."

[27] "Cymba"; that this word (meaning a skiff) also means the navicular ("like a little ship") bone in the ankle is confirmed by Vesalius (*De humani corporis fabrica*, 168, l. 9).

that he moved himself to and fro very fast, like a javelin's flight, more than twelve palms' width.

But what was a less extraordinary display, yet beyond all belief in human power, was this: after climbing up with weights from the area of the Jovian citadel to a very tall tower, he then climbed from the tower's top to a vertical wooden beam along a rope which had been set up so as to deviate more than three quarters of a right angle from the level. He came down again by a greater miracle than he had gone up, evidently about to topple down prone on his head. It was



noticed that he had sustained such power by trapping the rope with &1130 each big toe against the other toes, as if with iron tongs. There was no other way he could either climb up with the rope so vertical, or avoid falling headlong on the way down. While doing this, he wanted to support someone with him on his shoulders, a large reward being provided, but could not find anyone to fall in with such a rash plan.

So it is no wonder that some of the greatest princes have been delighted with such a spectacle, being something quite out of the ordinary, and that ordinary people have thought it the work of demonic skill, since it looked beyond human power. But the astonishment ended after one of them was induced by your generosity and persuasions to embrace Christianity, a rarity in our age, and he displays the same performances, and he was presented with your first name.[28] We have often seen him catch with a three-pronged wooden fork three rounded pottery vessels, not very deep,[29] which were provided with a hollow brass ball in the middle, the size of a nailhead, and furnished with silk round the ring, to prevent the contents running out; and barely moving his hand, whirled them rapidly round so that they escaped vision. The explanation is the metal's lightness combined with equilibrium, and the hidden power [638]of which we spoke above[30] in connection with the motion of a ring.

So though what we have said about tightrope walkers is quite close to a miracle, they still do less than what we read in Suetonius: that in the games the Emperor Claudius showed tightrope walking by elephants[31] — this is more

[28] "praenomen." A prominent instance of this practice was Leo Africanus (on him see n. to 160 [1560] in Book II), who was given the praenomen "Leo" of the pope who sponsored and adopted him. In the present instance, probably the persuasion came from Don Consalvo Ferrando, to whom Cardano dedicated the 1560 edition, and converted a tightrope walker.

[29] "cavus."

[30] At 1123 (1560).

[31] Not Claudius; Suetonius remarked in chap. 6 of his life of the later Roman Emperor Galba that Galba had presented this spectacle.

marvellous in them than in a child, because they lack reason, they are so much heavier, and they take their stand on &1131 two ropes, not on one. But so great is the power of training, and man's excessive greed, and the outstanding docility of this beast, which is closest to man in talent.

Rivers are crossed quite usefully by using leathery larger intestine; when required, it is strongly inflated, and with its ends closed is tied round below recesses.[32] In this way, cavalry and infantry take to rivers safely in severe circumstances, and at times have dared to cross using this expedient alone.[33] This will also take place quite safely with leather drums placed under the feet, and with a stick to which a drum is attached. Not just swimming across, but walking on water can seem something close to a prodigy. It is clear that here too, as in the case of tightrope walkers, what is needed is daring, practice, and notable bodily strength; if light weight is added, the spectacle will be more attractive, and I have noticed that some people have presented this. We have reported much above on the topic of magic, when we spoke about mirrors, and about the magnet of flesh,[34] both in the previous books of the present work, and also in those on medicine, and the ninth book on *Arithmetic*.[35] But for the present we shall address by headings only the issues we have not touched upon, so as to display by very few instances what the subtlety of the human intellect is capable of.

So to return to the subject: the case of the tightrope walkers is similar to that of those who carry a stick or a spear upright on their finger. Others carry a rod on their fingertip, tilted because of swords fastened in its bottom from the opposite side. An experiment anyone can try: with our fist alone, we break a stone as thick as &1132 a palm,[36] which can sometimes be attacked in vain with a hammer. This is the situation: the stone is laid out on a flat piece of wood, or better, on one of stone; it is lifted so that it is supported only by its other end, with no force brought to bear, and then the raised part is struck with the fist, and the blow crushes it against the flat piece and it is broken into many pieces. But if the fist strikes too quickly, or later than when it has touched the end surface of the stone, the blow fails and the stone is not broken. In this way we have used a light blow to break bricks.

While the end of the surface[37] was crushed at the same time as the force of the blow, the weight is linked to the impact, and the situation is just as if it

[32] "alae."

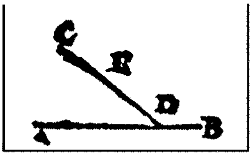
[33] The next three sentences first appear in 1554.

[34] "de carneoque magnete." This is a reference to the passage in Book VII, 499 (1560), where a physician spoke of the magnet or lodestone, and "kept promising that if it touched a stylus or needle, they could go completely through flesh without any pain."

[35] On this work see n. in Book XIII at 877 (1560).

[36] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

[37] "tabula."



were struck by a powerful blow from a hammer.[38] But I would like to prove this now. Let there be a plane surface AB, a stone CD set up on it, and it is propelled so violently upon AB that the air in between, perpendicularly below E, cannot slip out—every movement needs time. When it does not slip out, it must break the stone; because two bodies cannot penetrate each other, unless what is solid is split.

So it is clear from this that the wider the stone may be, and the flat surface of each is equal, and the more we raise the stone up, and the faster the blow is, the more easily the stone will be broken. We have seen how they break something placed on a rope. This is the power of practice, if brought to precision.

A new thick rope is snapped by skill: a &1133 nail is fixed in its end, or it is fastened by a hook, and then thrice, four times, or even more it is rotated in the hand, and finally the remaining end of the rope rides up close to the top of the palm, the part of the rope that relates to the nail rides up between the index finger and the thumb, and the top to the bottom of the palm; it is bent back again to where it had come from, and is carried round once or twice more; in this way it is snapped by a vibrating impact at the part which is ridden upon by the rope; the underlying rope prevents the hand coming to harm, and the final carrying round slipping. The rope cuts across the rope because of the impact, and particularly since the part between the hand and the nail is especially soft, and the hand sturdy, and the impact straight and fast. We have often seen this as far removed from any miracle, yet it does look miraculous. And there are people who undertake the same role of a fastening with both hands, and with hands alone snap ropes, and the kind of ropes that readily stand up to oxen.

I also have experience of this with another person supported on the shoulders, and two others of almost the same strength striving to pull them along against their will, though without a weight hardly one would be enough.[39] There are some things like this that depend on sympathy;[40] sympathy is what I call the concurrence of things without obvious rationale, just as I call their conflict antipathy. That both are present in things, innumerable instances show—such as, that a lizard enjoys the presence of a human being, although his presence is accompanied by some danger, which is why it eagerly avoids human saliva. People[41] suppose that horses are delighted with the society of rams, and also contribute to their health by their eyes, and consequently rams commonly feed in stables; certainly they feel extraordinary affection for each other. The monkey detests and is remarkably repelled by the &1134 tortoise. They wander about among animals,

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[38] The remainder of this paragraph with the subsequent one first appear in 1554

[39] The sense is not clear.

[40] On sympathy, see n. in Book XII at 823 (1560). Its definition here first appears in 1554, and the text of 1550 resumes just below the top of 1134 (1560).

[41] This sentence first appears in 1560.

plants, and stones, and man has no experience of them; he turns dumb, as is believed, if a wolf has seen him first—hence Vergil's line:

> Wolves were the earlier ones to see Moeris.[42]

This is not because of terror, for it does not happen to those seen by a lion or bear, and it was not fair that it happens when the wolf sees the human being first, but not when the human being sees the wolf first. But we have experience that this is sometimes the case; they do not become totally dumb, but they get hoarse. And since it did not happen always, people said that the reason it did not was that the human being saw the wolf first. So the reason lies in the eyes of the wolf; it has something harmful to man, by which his spirit is confined, and the violent exhalation of spirit needed for the voice cannot take place. For a similar reason it is said that if horses follow the trail of a wolf for a long time, their hooves are numbed; if the trail is fresh, it is distressed by the odour. Hence at times the [639] human being does not turn dumb, nor the horse numb, since there is some celestial impression that weakens and is made ineffectual with the passage of time, and smallness, and the condition of the subject, and contrariety of the creature that should be affected. On the same reasoning, people say that a wolf's tail hung up in the stall of oxen or horses puts them off their food. If this is not true, it still might be, since though hungry, creatures frightened by the smell will forget food, as happens to people too if greatly terrified.[43]

In fact the reason for antipathies and sympathies of this sort lies in concord or discord while the creatures were alive; for instance, when lute strings made from a lamb &1135 resound badly against those made from a wolf, although the same thing happens with almost all the sinews of various animals, such as the dog and the lamb. This occurs fairly clearly too in drums: in the presence of drums made from wolf hide, those made from sheep hide almost fall silent, and squeal. It should not seem remarkable that the hide of a lamb torn to pieces by a wolf should arouse itching; it is harmed by the terror and by the contrary nature. Even if death is the final penalty, the body is more affected in the one species[44] than in the other. A man struggling in the sea is more terrified than in the presence of the enemy. Either because of its smell or its species, a wolf's head hung up in a dovecot is believed to keep off ferrets and weasels. What is remarkable about that?—we would not go near a lion's head, except with an advance plan. Who could make these animals safe, in case behind the obvious head the rest of the body lay in wait? What is nearly remarkable, if true, is that a wolf's tail buried

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[42] Vergil, *Eclogue* 9. 51. Moeris was a sorcerer-shepherd, struck dumb when seen by wolves before he saw them.

[43] Sympathy and antipathy together are first introduced into the account here in 1560, and the account of "resonance" effects in the earlier editions varies slightly.

[44] "genus."

keeps off the flies. What is certain is that wolf dung, intestines, and hide, when eaten—or even just carried—ward off colic; these items actually strengthen that particular intestine.[45]

But strong organs[46] repel disease, unless weakened by an ulcer; these parts of a wolf reinforce the intestines, by drying, and also through their own nature, and by being very strong; a wolf even digests[47] earth, and never suffers from gluttony, even if it gets filled up after long hunger, and is always consuming flesh that is practically rotten. He is said to have a unique intestine, with all its parts of the same form and size, not coiled up as it is in the other animals, being nine feet long.[48]

I have not yet tested whether an oven-dried &1136 wolf penis, if chewed, can instantly kindle sexual desire and the power of having sexual intercourse.[49] It is not irrational, but to be able to do this all the time is ludicrous; it has been shown that the greatest and readiest stimulus to sexual desire is a fantasy of the one[50] we love, so as to win her.

More extraordinary is the tale that the tooth or left foot of a badger tied to a person's right arm strengthens the memory. Perhaps more credible is the account of Symeon Seth:[51] that partridge bile smeared on the temporal arteries so as to make its way inside once a month does a great deal to strengthen the memory. But honey does this too, and sharpens the wits, and when eaten makes a person diligent—which cress can do too. And a hen's brain benefits the wits and the memory, so much as to make some people who had started to become crazy recover their senses. But beyond this, honey offers a calm mind, and makes for considerable cheerfulness, by driving away anxieties. Eaten at supper like this, it makes sleep pleasant, just as cabbage makes it gloomy, and beans make it restless, and garlic and onions make it terrifying. This is the source of the belief in bogeys, which make people who feed on celery, chestnuts, beans, onions, cabbage, and French beans seem to be conveyed in a dream to various places, and there be influenced in various ways, according to their individual temperament. They are assisted in this by an ointment with which they coat themselves all over.[52] It is thought to consist of the fat of children dug from graves, and juice of celery and

[45] I.e. the colon, or large intestine.

[46] "membra."

[47] "concoquit."

[48] This sentence first appears in 1560.

[49] On Cardano's own impotence, see n. to Book V at 370 (1560).

[50] "rei quam amamus"!

[51] An eleventh-century Byzantine writer on dietetics and foodstuffs. For details see A. Kazhdan, "Seth, Symeon," *Oxford Dictionary of Byzantium* 3: 1882–83.

[52] The adjective "totas" here is feminine. The material to [A] on 1138 (1560) first appears in 1554. A shorter version of it appeared in 1550 at 1175 (1560).

&1137 aconite, also of cinquefoil and a soft kind of wheat.[53] It is beyond belief what huge things they convince themselves they are seeing: now happy things, theatres, garden plots, fisheries, clothing, finery, dances, handsome youths, and sexual intercourse of the kind they particularly desire, kings too, and magistrates with their escorts, and all the glory and pomp of humankind, and many other distinguished things, such as appear in dreams and in pictures, things larger than those nature has to offer. And instances on a contrary basis: grief, ravens, prisons, solitude, torture. And this is to be expected, although linked to sorcery,[54] for it must be converted to natural causes. I have frequently tried the often-celebrated ointment called "populeon," from poplar fronds, on the arteries of my feet and hands; some people even say also on those of the liver and temples, to achieve sleep in most cases, and in the greatest part of these to display cheerful dreams, because the juice of fresh fronds cheers the soul, and exhibits sights imbued with its clarity and colour; there is no colour more cheerful than green. Similarly too in food: most of the vegetables induce dreams, either because of their thinness, like honey, or because of being pungent, like garlic, or because of turbulence, like cabbage.

Then all the items that are not concocted, such as all the roots, induce gloomy dreams, but pleasant ones result from things concocted through thinness, such as honey and bugloss; there are actually some that are the cause of sleep, some the cause of dreams, some the cause of the qualities of dreams, others the cause of their representing the truth, or obstacles to their doing so. The causes of sleep are &1138 what weighs down and fills up the head; of this kind are cold and moist things, or else they pick up too much of one of these qualities. But what cannot stimulate deep sleep induces dreams; dreams occur more in the course of light dreams. Nightshade, and thornapple,[55] and anything that is very green display pleasant dreams, cabbage[56] being the only exception. But when beans have got dry, the dreams are terrifying. Agents that are smeared on do influence the spirits more, but induce appearances in dreams more. Things that have something burnt about them, such as soot, make people see torch fires. Theatres and garden plots, juice of celery and of soft bright herbs. Anything too dry makes many dreams appear, but unstable ones. I have not yet tested. [A] Yet people say that a stallion's teeth, hung either from the neck or the left arm, cure those who regularly see bad dreams. And that people who get up for such reasons in the course of sleep are freed, with the [640]cause removed.[57] It is my view that great care should be taken of one's sleep; apart from being essential for human health, it takes up a

[53] "siligo."

[54] "quanquam veneficum."

[55] "Malum spinosum," *Datura stramonium*, source of the alkaloids hyoscine and hyoscyamine, soothing but potentially poisonous.

[56] "brassica."

[57] The material from here to [B] on 1139 (1560) first appears in 1554.

third of a lifetime. So applications smeared on the temporal arteries and those of the hands and feet, and also more on those of the neck, where the arteries we call "soporific"[58] are situated, turn into vapour and exhalation, and immediately occupy the spirits and mind, so much so that even during waking hours they can cause many appearances to occur. The smokes of certain things behave similarly, being closer to poisons than to soporifics. For the most part, terrifying dreams either anticipate or follow great disasters; if they arise because of a memory, this has preceded a &1139 mishap, but if because of humours, they presage death or a grave disease—the reason for them lies in the body. And if they are prompted[59] by the stars, they indicate prisons, injuries, exile, and wasting of the body—an impression has no meaning apart from the impressing cause—the meaning lies in the human being. If this happens from the soul, it is evoked by sympathy,[60] and consequently means the loss of a beloved person. This should be like that, so that sleep is dissipated because of it; rest is then defeated by the condition.[61] Or if a little later, sleep may be entirely dissipated.

It is also a good idea to examine whether something violent has previously disturbed the soul: for instance, food or drink to excess, or of bad quality, or taken at the wrong time; or great agitation of body or mind, such as fear, and greatly; these are things that commonly stir up baseless terrors and unfounded hopes. But we have completely covered the interpretation of dreams.[62] There is no reason why I should explain how to generate wakefulness: camphor with vinegar smeared on the arteries, even if it does less good to the eyes, makes one stay awake, as do rue and castor.[63] [B] That smearing one's face with bear grease should extend the intellect has no apparent cause, even if true. But that drinking the marrow of a she-mule makes one stupid, even if it is possible, still is not certain, to my mind. But for the sweat of a she-mule to prevent a woman from conceiving when placed on the womb is quite probable. Yet for a black dog's eye

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[58] These are the carotid arteries running up through the neck to the brain etc., and named καρωτίδες according to Galen (*De placitis Hippocratis et Platonis* I. 7; K. 5: 195; ed. DeLacy, 1: 87) from the word καρόω which means "stupefy." But Galen (e.g. *De usu respirationis;* K. 4: 502–3) did not accept that obstruction of these arteries produced stupor. In fact in a human being this would create unconsciousness (and death), since they are major suppliers of blood to his brain, but Galen claimed to have succeeded in a dog in tying them with little obvious interference with its functions, and could not be aware that such an animal can draw on other arteries too for a sufficient supply to its brain (see also Galen, *On Anatomical Procedures*, 14. 7; trans. Duckworth, 210. This portion of the Galenic work could not be available to Cardano, since in his time it existed only in Arabic).

[59] "contingant."

[60] "consensus."

[61] "affectus."

[62] On Cardano's approach to dreams, see Siraisi, *The Clock and the Mirror*, chap. 8: "The Medicine of Dreams."

[63] On castor, see n. in Book X at 744 (1560).

held in the hand to prevent dogs barking and be no small help to thieves and adulterers could be possible, because of its smell; as is well known, dogs have a marvellous sensitivity to &1140 odours, even if very faint ones. One could test whether this is in fact true with a fresh eye, not one dug up long ago.

In that case, everything like this sometimes works and sometimes does not; not every rhubarb purges bile, nor does it every time; for instance, an old, empty, light and rotten rhubarb does it in a phlegmatic person and in a fairly cold winter, or in a sturdier body. So why do you want what is said here never to err?—when everything mortal is subject to error, and yet what I have said has been turned in every direction, and is what I have tested. It is said that a stone bitten by a dog and taken in a drink makes a person bark.[64] So if he barks, he does it either under coercion or willingly. If under coercion, it must do him notable harm. But it is not said to do harm. If he barks spontaneously, then either he is making fun, and so the trial is a joke, or he has lost his senses. One should then add, "given to drunkards,"[65] and I do not know whether even like that it would be true. But it does harm, and a stone bitten by a dog, if taken in drink, provokes to wrath. Perhaps they are right to say like this, that the foam of a camel given in drink to a drunkard make him demoniac; as he is excessively dry, it forcefully stirs up an already weak brain.

A ram's stomach cooked in water and wine and given in drink cures most diseases of sheep—a well-founded tradition, since it is sympathy.[66] Similarly, if a ram's horn is buried and decays, it turns into asparagus—though I have not tried this, I could believe it, from many witnesses. This is not far from a "metamorphosis," &1141 but decay, as I said elsewhere, is the mother of many things. The same horn, when buried near a fig tree, helps it to ripen its fruit quickly. The right testicle of a leopard, as much as anything, brings on menstruation. Its bile is a fast-acting poison that kills in a single day. Similarly, drinking a goose's tongue is wonderful for strangury; and its testicles, also a hare's womb, are marvellously good for procreation. The crayfish is good for this too; it has sometimes succeeded for me; hindrances should be got rid of, and the body and womb purged.

If children die at once and cannot be reared, a pregnant woman should zealously eat tortoise eggs. But if she eats quinces often, a boy is born, or a girl of talent and industry. No wonder, as those who are procreated by drunkards, or who eat onions, or often fast, or are too studious, are generally rendered insane; if their brain's food, and the spirits along with it, are brought into poor condition, they procreate progeny like their condition; and so gloomy people are born of gloomy people, or jealous ones of jealous ones.

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[64] "clamare"; the more usual word for "bark" is "latrare," but classically "clamare" could be used of animal noises.

[65] "ebriis datus"—sense unclear.

[66] On sympathy, see n. 40 above.

Thus quinces fend off vapours from the brain, which makes the substance of the infant's brain purer, so that the talent issues forth more distinctly, according to Galen and all medical witnesses. It is generally held that a monkey's heart prevents pulsation of the heart,[67] and cures epilepsy, and improves boldness and the intellect. Hardly surprising, since like is notably assisted by like; we see this in the stomachs of hens; when eaten before food, and &1142 provided they are being digested (they are indigestible),[68] they strengthen the stomach marvellously; this comes about because, as I said, what is nourished is made like what nourishes it. But some things are not alike, such as pear seeds, which are quite useful for the lung, as Simeon[69] records.

But to return to the monkey heart: they say that when placed under a sleeping person, it shows the sleeper wild beasts during sleep. The ash of a land hedgehog[70] dries up fistulas and all ulcers, and when eaten takes up the surplus moistness of the parts; its liver and kidneys are especially good, and it is collected by physicians. They say fleas assemble on its fat. I have found fleas gathering on the blood of a he-goat placed on the hearth, and no wonder: they go to what seems sweeter to them. I used to know, though I forgot, that fat smeared on a wooden ball attracts all the bedbugs to it. Then fastening a sword in it, he[71] used to pretend to chant spells over them, though they rush to [641]food, not to words. It was extraordinary to see that ball covered with bedbugs, so that you could hardly see the wood. Such things are so, and must be so, but they need to be known. People assert that a bat's heart prevents the egress of ants, but I think that sulphur blocks them, because of its strong evil odour. On trees, nothing is safer than water, as I have found; they are ringed round with wax, and the wax is filled with water. Aristotle recounts that they are repelled by origan mixed with sulphur;[72] this is reasonable, since both have a strong &1143 [wrongly numbered1149] heavy smell, and he is a trustworthy witness.[73] And it should not seem remarkable that the skin of a vulture's right heel placed on the right foot of a gouty person, and of its left foot on his left, can alleviate his pains. Similarly, an infant's umbilical cord, cut off at birth, and carried in a silver ring so as to touch

[67] This is presumably palpitation; Jean Fernel, an older French contemporary of Cardano, remarks (*Pathologia*, 5. 12) that it is an immoderate shaking, harmful through violent diastole and systole. So powerful, he says, that *often* it is found to have broken or displaced neighbouring ribs!

[68] "difficilis."

[69] See n. 51 above.

[70] The marine ones are the sea urchins, also prickly all over.

[71] It is not clear here who "he" is.

[72] Aristotle (*Historia Animalium*, 4; 543b22; Loeb 2: 71) said that ants were driven from their nests by applying origan with sulphur.

[73] 1550 includes here a complex recipe to use flying ants to provoke lust, not present in later editions used.

one's flesh, has helped many sufferers from colon pains before my eyes, so that with this to protect them they enjoyed many years of perfect health; perhaps their confidence did them good, for it is hardly credible that this could happen in all cases, as I showed above.[74] The value of what is hung up was always uncertain and suspect; waste not so much.[75] A friend of ours found great value for his gout from very large root of male peony, gathered on the day of full Moon, and hung round his neck; but I would not dare to say that it benefits everyone. But many reliable things can be drawn from our bodies, because of sympathy.[76] Mumia used to be the coagulated blood of Egyptian bodies, bodies buried with myrrh, aloe, and other perfumes, such as cassia and amomum.[77] With this type of medicament, blood would run from all directions,[78] and it was very useful for damaged and crushed entrails.

People who approve of the practices and language of the Greeks protest vigorously that they prefer the sick to die rather than use aids with which they have not been acquainted, so that this practice can pass away. And their contempt has grown because now bits of corpses are imported to us which are being conveyed in the Red Sea, where the &1144 winds are hot and dry and the local climate hot, in ships of the dead and dried up, and include those who have been suffocated in sand, to serve as mumia. Nevertheless, even this sort of mumia is not useless as a medicament to arrest haemorrhage, despite its foulness and grimness, so long as it is applied to the place. Everything trembles at its own like, especially when this like is decayed; for instance, dogs eat dog flesh more than human flesh or that of wolves, oxen, and sheep.[79] Hence arises the hatred of endearing oneself, and the poisoning of love. Indeed, so that I can distinguish the kinds of marvellous effects by headings: marvellous things happen in seven ways: either by nature, or by the powers of the body, or through talent or a property or definite but exceptional powers, or because the cause is deliberately concealed, or in a simple sense.[80]

I set out numerous instances of properties and bodily powers and deliberately concealed causes when I wrote of Damautus or (as others choose to say)

[74] Material from here to [E] on 1163 (1560) appears first in 1554, while 1550 includes instead a little intervening material about haemorrhage.

[75] "iactura non adeò"—the meaning is obscure; possibly "not up to this point a loss." "Iactura corporis" means wasting of the body a little earlier, at 1139 (1560). "Iactura" means jettisoning, loss, sacrifice, wasting, loss, deprivation, expense, cost.

[76] On sympathy, see n. 40 above.

[77] A spice plant of the ginger family, or the spice from it.

[78] "Hoc medicamenti genus undecunque sanguis flueret,"—syntax obscure. I have translated as though "genere" was to be read instead of "genus."

[79] "Ut canes canum corpora plus quam hominum, vel luporum, boum autem et ovium edunt." The thought is obscure.

[80] "simpliciter."

Dalmago,[81] and the Turkish tightrope walkers,[82] and wove my account of the wolf.[83] I have illustrated those causes that act through manifest but exceptional powers by the example of peony root. I shall add many examples hereafter of those that simply have an unknown cause; this kind relate to spells, poisons, for instance, relate partly to the fifth, and partly to the seventh kind.

What is left is for me to mention those marvels that happen by nature, and which take place through the greatest powers of the intellect. We have so far recounted many examples of nature; but of those that relate to monsters, &1145 not through the failure of the craftsman but through his assiduity, there was one that on the authority of Konrad Gesner[84] was discovered, with its whole body and face human, but the feet and nails of an eagle, and mute, in 1531 in the pass of Hamesberbium in Meissen; he used to describe it as yellowish, bearded, and with a sort of crest of hair.[85] On the top part of the back and of the legs[86] (which were human) and the arms alone, it was hairy, horizontal, and with a tail. What could one say, except that an exposed infant had been made into a quadruped, without a teacher? Hence the failure to learn to talk, and the long nails like those of wild beasts, and the other results of a rough location. Fed by a beast's kindness (whatever it was), then on country fruits, hidden in caves, it had lived through the power of its destiny and its native toughness, rather than through any reasoning. Similar too were two captives of Albertus Magnus,[87] one male and one female, in the forests of Germany—I might call them quadruped human beings.

These are uncommon happenings, from uncommon causes. And the extraordinary features seen in them are not in others, for that reason. No one is to blame us, because we are not in ignorance. And it will suffice to add three instances of marvellous talent. First, in which we seek what the question is. Second, in which we can always make progress, yet never reach a precise knowledge. Third, because it is beyond human power, and had not to slip away unnoticed.

So the first is when amid capable people, we wish to make a coach or a ship, and it does not tell us how many miles it covers. A wheel with a &1146 circumference of twelve and a half feet, and a drum round an axle with a tooth, which when the wheel is turned engages with a wheel of four hundred teeth, and transfers one of them. Thus when four hundred revolutions of the first wheel have been completed, from five thousand feet one thousand paces will be covered.

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[81] See n. 3 above.

[82] At 1126 (1560) onward.

[83] At 1134 (1560).

[84] Reference not traced in Gesner's *De rerum fossilium, lapidum et gemmarum maximè, figuris et similitudinibus Liber*.

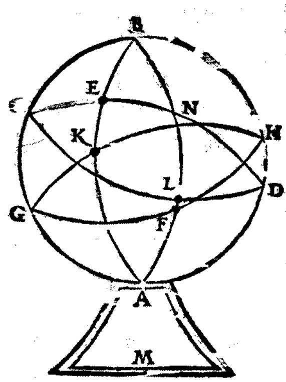
[85] "subflavum, barbatum, et quasi pilis cristam"— syntax unclear.

[86] "Dorsi summa parte et sylvestri crurum.."— "sylvestri" can mean "wild" or "savage," but I cannot translate it here.

[87] On Albertus Magnus see n. near beginning of Book I.

And when this wheel has been turned by another tooth, it can uncover a hub,[88] from which a stone can drop into a brass vessel below, so that from the noise and the number of little stones, the number of paces is shown. Or else, by turning a pointer it will show on another wheel the miles. Thus, as Vitruvius explains,[89] it is easy in ingenious contrivances to attain a precise acquaintance with things. There is an example in studies;[90] for instance, when celestial circles are displayed here, and in the ratios of spherical circles very precisely proved by their sines.[91] And particularly when the distance of a place is discovered through use of the meteoroscope,[92] we know its longitude and latitude; or with the distance and latitude known, we get to know the longitude.

[642]Let there then be a meridian circle AEBF, mounted on a base AM. Let the poles on it be represented at KF and your head[93] at E. Another unmoving equatorial circle is ABCD, fixed on the base AM, and cutting the previous circle AKBF at right angles. Let there be another circle FGKH, through the poles and capable of turning on pegs in the poles themselves F and K. Let ther be yet another circle CEDL at the summit, capable of turning on pegs. Let there be a distance EN, marked and straight, and let those degrees in CED through EN be numbered (by the division of individual circles from these into 3,600 degrees) &1147, and let CND be established, on a straight route from



[88] "modiolus."

[89] Vitruvius (10. 9. 1–4) provides the information that Cardano conveys here.

[90] "contemplationibus."

[91] "sinus"; an English mathematician, Robert of Chester, who flourished in the middle of the twelfth century, "was the first to use the word 'sine' in the modern sense," (G. Sarton, *Introduction to the History of Science*, 3 vols. [Baltimore: Carnegie Institution of Washington, 1927], 2: 126, 176) as translation of an Arabic word which was the trigonometric function's name. The Latin "sinus" means a bay or bosom, and the translation is due to misunderstanding; the original Sanskrit word was *ardhajya*, meaning "half chord," which in Arabic was shortened and transliterated as *jyb*. In Arabic, vowels are not spelled out, and so the word was misread as *jayb*, meaning "pocket" or "gulf" (O. Gingerich, "Islamic astronomy," *Scientific American* 254 [1986]: 74–89).

[92] An instrument the same as, or similar to, an astrolabe. The planispheric astrolabe, an instrument initially developed some two millennia ago, displays the sky projected on the plane of the equator and has moveable parts enabling reckoning of the position of celestial bodies at specified dates and times. For a concise introduction to it, see D. Lindberg, *Beginnings of Western Science* (Chicago: University of Chicago Press, 1992), 264–67, and for detailed accounts, see J.D. North, *Chaucer's Universe* (Oxford: Clarendon Press, 1988), and D. A. King, "Astrolabes," in *Medieval Islamic Civilization*, 1: 73–76.

[93] "vertex tuus."

your city to the place N, and where the point N falls, let GKHF be drawn, a movable meridian circle.

So you will have through the arc KN the latitude of the place, or the elevation of the pole, and through GC the difference between the longitude of the place N and that of your town; and since the longitude of your town is already known, so too will be the longitude of N. But if the height[94] N becomes known, and the straight path EN, then by drawing round the circles CED and GNH till the ends of the arcs EN of the straight distance, and KN of the known &1148 height of the place N, meet in one point; then the arc GC will be known, that is, the difference between the longitude of the place N and that of your homeland.

And it is obvious that since the longitudes and latitudes of the places are held on a contrary basis, the distance too will be known. If you want to do this, so that the instrument can serve for any region, you will make pegs EL, movable in a meridian circle AKBF, so that the top of your head can be located under any altitude. Further, make divisions in individual sets of ten, bold, and in sets of five, less so, and then in sets of five hundred in a golden colour, so that they can be carefully distinguished, as in steelyards. The number is not essential, since the starting point can be set up anywhere. We also achieve this by demonstration, but in a more difficult fashion; and all this must be precise. Though what is always better to achieve is the ratio of the circumference of a circle to its diameter [π], discovered by Archimedes with wonderful skill. This being very easy, I would like to append it in four words. It needs three assumptions: first, that the circumference of a circle is greater than the sum of the sides of an inscribed figure, and less than that of a circumscribed figure. This is apparent about the inscribed figure from the definition of a straight line; about the circumscribed figure, though some people think this obvious, it is proved by us in the books of the *Elements*[95] by antiparalogismus.[96]

The second assumption is that with any known line located in a circle, the straight line subtense of its arc divided in the middle will be known.[97] Though

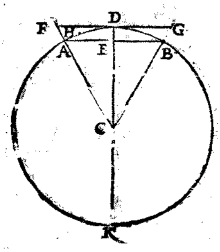
[94] "altitudo."

[95] Cardano had published from 1534 *Novae geometriae libri quindecim*; Maclean (*De libris propriis*, 58–59), describes the scope of this work, which Cardano modelled on Euclid, but the work does not appear to have survived. Also, in the present work (940–52 [1560] in Book XV) Cardano outlines a geometrical treatise to supersede Euclid, but the word "antiparalogismus" does not occur there. Otherwise it is difficult to guess which of his works is intended here.

[96] The meaning of this word "antiparalogismus" cannot be traced in the usual works of reference, including the great *Thesaurus Linguae Graecae* of Henri Stephanus; it may be a mistake for some other word.

[97] "nota quacunque linea in circulo collocata, illius arcus per medium divisi, linea recta subtensa cognita erit."

this was proved by Ptolemy,[98] I will still make the issue clear with a procedure in &1149 two words, so that everyone can have a basis for discovering the proposed ratio.



Let AB be known in proportion to BC, and let the arc AB be divided equally at D, and let AD be drawn; I say it is known; when DCK is drawn, from the demonstrations in Euclid EA will be in mediate proportion between KE and ED, and the square of DA will be equal to the squares of AE and ED.[99]

From the fifth of the second book of Euclid's *Elements*, I will withdraw the known square AE, because AE is half of AB, from the known square CD, and let the known square CE be left behind: therefore CE. Hence when CE has been removed from CD, there will remain the known ED. I will therefore link the squares AE and ED, and from the penultimate theorem of the first book of the *Elements*, I shall have the square AD as known.

The third supposition is that with the side of the figure inscribed in the circle known, I will also know the side of the circumscribing circle. Although this is assembled by Euclid in the fourth book of the *Elements*, I will still append it here in a word, so that we can have a demonstration with a procedure. Let a side AB of the inscribed figure and a side FG of the circumscribed figure be contained within the same angle at the centre, and let AF and CBG be drawn. &1150 Since AB is known, AE is known, and accordingly KE and ED, as was proved. But as CE is to CD, so is AB to FG. So with AB drawn to CD, and with what is produced divided through CE, FG will turn out known. So with AB assumed as the side of a hexagon, which from what Euclid proved is equal to half the diameter, from the second assumption I shall have the side of a figure of twelve bases, and from the same one[100] of a figure of 24 bases, then of 48, then of 96, then of 192 and 384 and 768, and I can go ahead with error, and indeed without extraction of roots.

Thus for instance, with the situation in a side of a figure of 768 sides, I shall have on the third assumption the side of a circumscribed figure of 768 of them; you will multiply[101] both by the number of sides, that it, by 768, and you will have the circumference of the internal and external figure, and their ratio to the diameter of the circle. But the circumference of the circle is greater than the

98 I have not identified this proposition in Ptolemy's *Theory of Visual Perception*.

99 From the properties of right-angled triangles: $AD^2 + AK^2 = DK^2 = (DE + EK)^2 = DE^2 + 2DE.EK + EK^2$. And $AD^2 = AE^2 + DE^2$, and $AK^2 = AE^2 + EK^2$. So DK^2 also $= 2AE^2 + DE^2 + EK^2$. Then cancelling out, $2AE^2 = 2DE.EK$, i.e. AE is in mediate proportion between EK and DE.

100 But 1560 reads "eandem" instead of "eundem"; "suppositum" is of course neuter.

101 "duces."

circumference of the inscribed figure, and less than that of the circumscribed, so from the first assumption I shall have the ratio of the circumference of the circle to its diameter, between which the ratios must lie, and yet it cannot reach perfect knowledge and a limit. From which it is clear that Archimedes had no need of what Ptolemy discovered, nor of tables of sines,[102] and geometry could reach this state of [643]knowledge more exactly and purely without them than with them.

But what cannot be achieved is the projection[103] of a sphere on a plane without enormous error.[104] Ptolemy, I say, explains how to project a part very close to a fourth part; but in relation to the whole it should first be supposed necessary for what is linked to be furthest apart. &1151 When you wished to project divided parts in this fashion, I already explained it to you above, almost without any error. But if we suppose that AB is a straight line from pole to pole, all joined and continuous, and CD is equal to it, and another CE is also equal to it, and linked directly, and ED will be twice AB. We will divide CD and CE equally into four parts, so that EF is one quarter of EC and CD, and we will draw the arc FHG equal to ED. We will do it this way: from what has been shown here, it is accepted that the ratio of the circumference of a circle to its diameter is very close to that of 47 to 15,[105] at any rate in easy numbers. So supposing the circumference of a circle is 360, as Ptolemy does, the diameter of the same parts is 115 — the difference is tiny.[106] But Ptolemy puts it at 120. You will seek out in the table of arc and chord, an arc which is to be one and a third times its straight line, with a twenty-fourth part deducted, and its straight line; you will accept it without diminution. There will be about &1152 147 degrees.[107] Then divide FG into so many parts, and beside them adopt two lines which are 60, from which and FG a triangle is made and you will have a cone for a centre. Then after drawing FHG, you will mark out an equal line above K and on the same semidiameter, a

[102] Ptolemy did not prepare tables of sines, but he did prepare exceedingly elaborate tables of the chord function, first devised by Hipparchus in the second century B.C. This function was based on a circle divided into 360 degrees with each degree divided into 60 minutes. The radius of the circle is then $360.60/2\pi = 3438$ minutes and the chord function Crd of Hipparchus is related to the sine function by (Crd 2a)/2 = 3438 sin a. See http://www-groups.mcs.st-and.ac.uk/history/Biographies/Hipparchus.html.

[103] "descriptio."

[104] However, Gerard Mercator (1512–1594) used his own projection first in 1569, and other projections earlier.

[105] That is, 3.1333. . .

[106] 0.4% in fact; but the 22/7 of Archimedes (see 988 [1560] in Book XVI above) is much better, within 0.04%. However, Ptolemy did obtain, using chords of a circle and an inscribed 360-gon, the approximation $\pi = 3\ 17/120 = 3.14166$, which is better still: within 0.002%.

[107] "partes"; working with θ = half the angle, the arc (θ radians) is said to be the chord (sin θ) multiplied by 4/3 and by 23/24, i.e. by 1.278; Cardano says that $\theta = 73.5^\circ$, but in fact it is about 67.7° This sentence first appears in 1560.

midpoint AB, which is to be LKM, so that half of it protrudes on each side; then taking the table of parallel circles,[108] you will mark out each of the circles on the same centre in the required distance on the near and far sides of LKM, and with the required size, by extending those[109] that are closer to LKM beyond the lines that emerged from the common centre to L and M. And the closer the parallels get, the more exact is the plane projection.[110]

Then you will divide each of the circles into 360 degrees, and draw through them lines in place of meridians from pole to pole, which will be neither straight lines nor portions of circles, but will need to be drawn in relation to the symmetry and tilts of the eye. So here you will have longitude twice latitude, as on the globe's surface, and the distance of the circles preserved. The meridians too will appear no larger than they should, except through obliquity. Hence this kind of transfer, from a rounded figure to a plane one, will be seen to outdo them all, and was our shared discovery for the projection of heaven and earth. But as I said, someone will perhaps not judge this and its like as to be included among the marvels—but only include poisons and other similar things.

&1153 Further, there are four kinds of poisons: in inanimate things, in plants, in animals, and in human beings. In human beings there are eleven sorts: some win love, some sow hatred, some cause wasting, others kill off completely, others again evoke lassitude, others make people perform divination, some cure diseases, some enable the impotent to make love, some increase luck, some are totally unlucky, others stir the mind. Those that stir the mind are also of seven sorts: some evoke terror, others daring, some grief, some madness; others cause spectres to be seen during sleep, or even genuinely and while awake. But while people are awake, the things that make spectres appear to relate to an absurd skill or to demons, yet sometimes to poisoning. There are also those that induce numbness not only in men's minds but also in their bodies, so that some of them have an undisturbed mind, and others do not feel tortures.

The reasons for these are four: the manifest powers of things, and the hidden ones, and faith, and something unknown to us, whether it is demons or lower beings or something better and more distinguished. Matter in food, drinks, in hanging, lights, fumigations, couches, touch, words, in images at the house threshold,[111] and marks that summon characters; in making of sacrifices, mental strokes,[112] promises, murders, sacred and secular processions, and endless other events which would take long to mention. The slightest part of them is permissible—those that come to a good end, and the one that relies on natural powers

[108] Evidently lines of latitude.

[109] "eos"—cannot be "lines," can be "circles."

[110] "complanatio."

[111] "praeliminaribus figuris"; "praeliminaris" is not in *OLD* nor *L&S* nor *DuCange* nor *Thesaurus Linguae Latinae*, so the translation is a guess.

[112] "concussionibus."

or on &1154 simple supplication. I will include examples of others, so that people can grasp that little confidence is to be placed in these and their like; none of those that lack a natural subject is long-lasting, and is more often deceptive than effective.

But if it operates to the advantage of faith, is it not a very vile and ungrateful person who makes use of a gift against its giver? And people should know that even if inappropriately-sought responses arrive to their prayers, how little usefulness these responses are going to contribute. And such approaches do not enrich more than the prosecution of business, or than striving to be wise,[113] or to end up quite easily with distinction in the art of war, than through vigorous deeds. Again, the life of all these people is usually scandalous, and disastrous, their reputation tainted, their standing despised, and their end very wretched. Who in our own time has promised more of this sort than Cornelius Agrippa alone, and everyone knows of his mishaps, his life, his poverty, his decease?[114] And among the princes, Ludovico Sforza was the only one of his family to die wretchedly in prisons. And his cousin[115] the Bishop of Lodi,[116] while paying attention to such matters (it was almost beyond belief), himself died in poverty, though he came of noble blood and was as I said a bishop. Their resources are very safe, and their revenues as secure as can be Who used to take more delight in these matters than Pope Martin the Seventh,[117] since as it is said, he also [644]carried in his bosom someone free of these superstitions?—someone who was among the very few to be deprived of his position by a Papal Council, in a very rare instance.[118] Finally, this will be of advantage to anyone &1155 reciting such things to mortals, so that those who do not approve can be safe from the crime of these people,[119] and know what should be accepted and what avoided; many people turn out so fearful and superstitious that while keen to avoid what should not be avoided, they get superstitious in a fruitless flight from superstition; superstition occurs not just when we do what ought not to be done, but also when we avoid what ought not to be avoided.

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[113] "quàm mercaturam exercendo, aut sapere, quàm studendo,"—syntax loose.

[114] On Agrippa, see n. to 937 (1560) in Book XV.

[115] "patruelis": child of a paternal uncle.

[116] About 30 km SE of Milan.

[117] There was no Pope Martin VII. Martin *V* was pope from 1417 to 1431, and was the individual elected by the Council of Constance in 1417 to replace the three claimants it had dismissed. Cardano's account seems confused. See P. Stump, *The Reforms of the Council of Constance* (Leiden: Brill, 1994).

[118] I find no evidence that this person could have been Pope Martin V himself.

[119] The sense is unclear.

These skills flourished while the true light of Christ had not yet risen for us; but that they had little power is shown by their inventor, Zoroastes[120] himself, despoiled of his kingdom and his life together by Cyrus Cambyses. Pausanias[121] indeed recounts, that in the little town of Pionia in Mysia[122] near the river Caicus, while sacrifice was being made to Pionis (he came of the descendants of Hercules), the smoke of Pionis puffed out from his tomb. What is there actually to prevent this having been done by a trick, assuming that under the altar was a channel heading for the tomb, and that at the beginning of the channel pitch and styrax,[123] or incense or something other than what is being burnt as an offering on the altar (either on the pattern of waters, or on the pattern of Hero[124] when he explains that the temple doors opened of themselves during the sacrifice) was used to make smoke burst out of the tomb? But it could exist from another natural cause without a trick. And in Hypoepis and Hierocaesarea, towns in Lydia,[125] he saw ash on an altar, like no other colour, and when the barbarous prayers were poured forth and a heap of dry wood was piled on top, it would always emit flame, and consume the wood placed on it.

This could come about in many ways: either if the altar was hot, or if someone spat on it, would not lime be kindled by water? &1156 And we will explain later on[126] how to make a stone that is ignited by any moisture. What other stronger evidence do you wish from the ash, rather than in words, and than the ash's colour, different from ashy? It is possible to perform these portents in so many ways that I need not dwell on them: the fire could lie hid in the ash, as it often does in soot, when it is tiny. The tale he tells is different when he says: in the district of Methone, when the African wind used to knock off the vine shoots, two people would hold a cock with two white wings on each side and pull it apart, and running round the vines with a piece of it on the other side till they met together, they would bury the cock, and the wind would stop.[127] This conviction can do much towards deception, and the more so if it is fuelled

[120] Zoroaster, rather than Zoroastes (c. 630–550 B.C.), prophet in Persia, who maintained the practice of fire worship and the predominance of a single main deity. Mentioned by (among others) Pliny, who stated that on the day he was born he had laughed, and his brain "throbbed so violently as to dislodge a hand placed on his head—this foretelling his future knowledge" (*Nat. Hist.* 7. 72; Loeb 2: 553) also that he was the originator of magic, and lived 6,000 years before Plato's death (*Nat. Hist.* 30. 3; Loeb 8: 281).

[121] *Description of Greece*, 9. 18. 4; Loeb 4: 249.

[122] A region in the NW of Asia Minor.

[123] A gum derived from the tree *Styrax officinalis* (*OLD*).

[124] See n. in Book I at 12 (1560).

[125] A territory in the west of Asia Minor.

[126] At 1167 (1560) below.

[127] Not Methone; *Methana*. Pausanias, *Description of Greece*, 2. 34. 2: "The wind called Lips, striking the budding vines from the Saronic Gulf, blights their buds. So while the wind is still rushing on, two men cut in two a cock whose feathers are all white,

by religion. Then in some places the gusts of wind are quite brief, very rarely long. Perhaps faith combined with the genii themselves[128] has some effect. Or the event itself follows some hidden natural cause, or there is a demon, who if aerial controls nothing more than air. Hence storms often break out while they are being conjured. Much occurs in these circumstances as if things existed that do not. A quite remarkable case is the bronze stallion that he[129] says existed in Heraclea in Elis, a province of the Peloponnese, in a place named Quialten, with its tail docked, and in other ways far from handsome; the other stallions used to try to cover it, and did so with such determination that they slipped off because the bronze was smooth, and with repeated mounting their hooves got broken, till they were driven off with clubs. They used to whinny as if they had come upon a mare, and of the many statues they assailed this one and left the rest untouched. &1157 Perhaps that poetic remark would present itself to us here: "Whatever untruthful Greece hands down in histories"[130] is what I produce, so that my book can get filled (as some people do), even if it cannot be justified. But I regard Pausanias as guiltless of that failing, no less than one of the Italians; in relation to what he saw, the examination done in our own times confirms his account. What is there absurd in Xenophon or in Thucydides? Herodotus and a number of others impaired the Greek reputation for history, but anyone can separate the fake from the genuine. It is accepted that the horse was created by technique, and whoever was the sculptor, he worked by natural, not demonic, aid—I am not greatly surprised, whether he mixed in to the raw material of his statue what some people call hippomanes,[131] or the blood of a menstruating mare, or rather its seed, or some other philtre that drives stallions into sexual frenzy. What preoccupies me more is that when these agents were mixed with molten brass, they did not lose their powers, and when burnt retained the strong odour of smoke, not of poison. Then even if they had been able to retain it, how could they do it for so long and over so many years? Or if the philtres were not totally mixed in the brass, how did they not rot? It is probable that horse semen was concealed in the entrails, and mixed with a gumdrop not liable to decay, with some orifices remaining,[132] or even that semen previously heated, to prevent

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and run round the vines in opposite directions, each carrying half of the cock. When they meet at their starting place, they bury the pieces there."

[128] The patron saints of the places, perhaps.

[129] Pausanias, *Description of Greece*, 5. 27. 3–4. The place he names is not "Quialten" but Altis, in Elis.

[130] "Quicquid Graecia mendax mandat in historiis, me adducere: ut quorundam more impleatur liber, si non potest absolvi." The original (Juvenal, *Satires*, 10. 174–175) runs: "Quicquid Graecia mendax / *audet* in historia . . ."—"Whatever untruthful Greece dares [to relate] in history . . ."

[131] "A mucous secretion discharged by mares on heat" (*OLD*).

[132] Presumably in the casting.

it rotting, had excited the stallions, especially in combination with the statue's shape. Horses have vision with a blunted edge, and sometimes whinny even at painted horses — no wonder they are deceived by a statue and an odour. But they had detected the brass one; then they became possessed by concentrated frenzy, and the hoof &1158 by which they press on the statue loses feeling entirely, and the odour and shape still stimulates them. There is no reason to be astonished about their sex; stallions in fact distinguish sex by smell, not by sight. The sculptor decided to change the sex, either to make a greater impression, or because like Affranius[133] he was displaying habits from his own artistry; for this would not do anything well matched to the work and the trick.[134] He was perhaps arranging for the tail to be a good deal raised, so that the odour would arouse the stallions more. What am I to conclude about those who are said to check ice in movement[135] by charms in Swabia?[136] These tales are too much to believe. Other people attribute these events to the stars. Ioannes Leo[137] recounts that on the top of a Moroccan citadel there are three golden apples weighting 1350 pounds, and many kings, being in want, have tried to carry them off, but have always been hindered by unfortunate circumstances. People say that they were cast[138] for the price of the necklaces and gems of the wife of king Jacob Almansor,[139] and were armed with the power of stars making common cause and with spells, against the people who had planned to carry them off. And if there is gold there, not some

[133] A*f*ranius [sic] was an early Roman poet, of whom Cicero wrote (*Brutus*, 167; Loeb, 145): "Upon him [the orator Gaius Titius] the poet Lucius Afranius strove to pattern himself, a man of cunning wit, and as you know, in his plays really eloquent." On his artistry: Aulus Gellius (*Attic Nights*, 13.8. 1–3; Loeb, 431) remarked that Afranius "wisely and prettily called called Wisdom the daughter of Experience and Memory" in his now lost comedy called *The Chair.*

[134] "praestigias."

[135] "glacies concitata."

[136] Baden-Württemberg and parts of Bavaria and Switzerland.

[137] On Leo Africanus see n. to 160 (1560) in Book II.

[138] "conflata."

[139] The mosque with gold apples, known also as El Mansour's mosque or the Kasbah's mosque, is in Marrakech in Morocco. The name of the mosque was initially "the mosque of El Mansour," because this great Caliph (938–1002; diversely recorded as Yakoub El Mansour, Abu Yusuf Ya'qub al-Mansur, Al Mansor) built it. In 1569, an explosion led to reconstruction as "the mosque with gold apples," referring to the golden copper balls that are on the top of the lantern of its minaret, and which were thought to be made from the gold of the jewels of El Mansour's wife. Leo Africanus (ed. Hakluyt, 2: 273) mentions the wife of Mansur getting precious jewels from him, but doesn't name her; she is named "Hermione" just below in the present work; see n. 141 below. She "caused those three sphears to be made of the . . . jewels which her husband Mansor bestowed upon her, and to be placed upon the temple which he built." Later attempts to make away with them, wrote Leo, were dogged by "some great misfortune or other."

other metal surreptitiously substituted by princes, with a rumour due to popular fear in existence, the discussion[140] will need to be moved to what was written above about the necklace of Hermione.[141]

The same Leo tells that in Fessa,[142] the most important town in Africa apart from Cairo, the soothsayers do predictions from shapes made in the sand, so precisely that those who experience them are dumbfounded.[143] Matthiolus the physician[144] reports that near Rome there was an old hermit to whom many people used to come with the [645]name of those who had been wounded by snakes. The hermit used to &1159 ask the messenger, "Did he want to undertake the cure himself on behalf of the invalid?" And with the messenger concurring, he used to tell him to press his bare foot on the earth that he marked round with the edge of a knife, and then he would move the foot aside and write these words: CARO CARUZE SANUM REDUCERE, PUTA SANUM EMANUEL PARACLETUS, and scrape off with the edge of the same knife what he had written with it, so that no trace remained. He would put all this earth into a dish full of water, leaving it till it had all settled, and after sieving it with the messenger's shirt, would give it to him to drink, and the absent invalid was instantly cured. Just give me the explanation of this! You will perhaps say with a grin, "I write unheard-of stuff too! — its reliability rests with its author." But when I brood on what happened to the son of Hieronymus Legnanus[145] in our town, I cannot help being astonished. He used to suffer before my eyes from an abscess between his pubic region and his navel, and at its worst, when it had turned to an ulcer, all the most famous surgeons despaired of his recovery. This was when he was a boy

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[140] "ratio."

[141] Almansor married a daughter of Sancho II Garcés, king of Pamplona (Navarre), and this daughter became a Muslim (*New Encyclopedia Britannica*, 10. 404) but her name is not stated; it is said elsewhere to have been "Almansaris." However, Cardano had referred earlier in Book VII at 470 (1560) to a "Hermione," and the n. there explains Nenci's surmise that his "Hermione" is really "Harmonia," who was reputed to own a ring (not a necklace) that brought misfortune to all its owners or wearers.

[142] Fez (now Fès), in Morocco; Hakluyt, *Principall Navigations* (Glasgow, 1904), 6. 143) states that "the principall citie of Fes is called Fessa."

[143] In Book III of his *Historie of Africa* (trans. Pory, 2: 459–62) Leo describes at length the elaborate procedure which he viewed as astrological or Cabalistic; it involved complex drawing in "an ashe-heap or some other place," and "These practitioners are never found to erre, which causeth their arte of Cabala to be had in great admiration: which although it be accounted naturall, yet neuer saw I any thing that hath more affinitie with supernaturall and diuine knowledge."

[144] Matthiolus (Pier Andrea Mattioli; 1501–1577) was a physician who published in 1544 a major commentary on the works of the botanist Dioscorides. See n. to 190 (1560) in Book II. This tale has not been traced in his *De plantis* (Frankfurt, 1586).

[145] Not traced, except that "Legnanus" may have been provost of Vercelli, an Italian town.

of eight, and as they used to say, even faeces tried to emerge through his navel, though I did not see this. He had wasted to the limit, and fell into the hands of one Antonius, from the village of Gallarate,[146] who administered well water with some words spoken over the wound, and cured him. And when I visited his sick mother some months later, and thought that he had died, this boy ran up looking like a monster; the disease was so extensive and he had stayed so bowed that his chest and head were parallel to the ground, he had taken the shape of an upright &1160 sundial pointer, and the wretched lad lived on like that though well-born; his father is a solicitor[147] and a distinguished advocate. Such occurrences surely command much astonishment; but for him to be capable of cure by the root of black hellebore stitched between the flesh and the hide of a beast of burden bitten by a viper is more an achievement of magic than of veterinary skill, yet does have an obvious rationale—though it does possess a significant power of attraction, it summons the powers of poison scattered from all round away from the heart to the opposite arterial apertures. For every artery with sensation[148] (apart from the one in the lungs) has one aperture in the heart and another under the skin.[149] What arteries do in animals is almost the same as what roots do in plants. Hence it is said that in northern parts plants flourish that are perpetually in leaf, though it is out of line with the nature of the kind that in their roots round masses of snakes lurk. This happens especially among birch trees; the excess humour is dried up, and the tree itself gets warm with the venom of the snakes; the lazy crowd of people reckon these are sacred trees.

There are other things that disturb the mind on a similar basis, such as wine lees, henbane, and spurge root, especially the sort called cyparissias.[150] This is why birds and fish and anything with a weak brain are driven out of their minds; some, such as birds, have a weak brain because they are small, others because they are cold, like fish; others because of incompleteness, like mice and rabbits; hence if you deal a rabbit even a gentle blow with your hand on the back of its head, it dies at once. But such attacks are hardly enough for a human being. Agents that induce lassitude should be excessively &1161 moist and cold; they cannot provide the matter for such a heavy and steady sleep. But if you mix in a moderate amount of these, they will still not create heavy sleep. If you use too

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146 Gallarate is in northern Italy, about 40 km north west of Milan. Cardano lived there in 1532–1535.

147 "tabellio."

148 Jean Fernel however, a near contemporary of Cardano, does not quite see things like this; for him (*Physiologia*, 1. 13) there are arteries and veins whose final terminations are in the skin, to which they supply nutriment and spirit, and it is the nerves that mediate the skin's sense of touch.

149 The remainder of this paragraph first appears in 1560.

150 "Cyparissii"; instead of a cypress, this is apparently a kind of spurge, a species of tithymal; in Pliny (*Nat. Hist.* 26. 70; Loeb 7: 315) it is spelled "cyparittias."

much, you will kill the person—and it will take over the heart rather than the brain. So what should be mixed with these is what makes rapidly for the head. All such things are rarefied, so that they break up readily into vapours. What is rarefied is very hot; so this medicament should comprise cold and moist, also hot and rarefied constituents. What is thoroughly cold and moist cannot be cooked, and what is not has a heavy smell. But what smells heavily and is combined with hot and rarefied constituents smells a lot; the smell's position is in the rarefied substance, the hot and the dry. So what can in itself evoke lassitude is revealed by its heavy odour. But there are people who mix it with wine, and then in addition to lassitude, when they come round again their minds are damaged.

Consequently those who administer such things deserve punishment as much as those who administer poison. They usually do it to consummate adulteries.[151] But it is possible to evoke lassitude by external odours, whenever what is very rarefied is mingled with soporifics. These agents serve to abolish the insomnia of the studious; it is they especially, and the old, that are troubled by insomnia. Fruit marinated in opium and clotted mandrake juice,[152] wine lees and civet can achieve sweet sleep in generous amount. But once more, good is often converted into ill. There was Nelphus, about whom a &1162 [wrongly numbered 1062] neat ode of Aurelius Augurello[153] survives covering the story of what happened. He has come out victorious in a joust at Padua, and put down his helmet, so as to breathe, and was killed by those who were jealous of him for being a plebeian, with the copious amount of opium smeared inside it; the heat of the helmet[154] and his spirits had absorbed all the deadly vapour held within the headpiece.[155] From the heat, all the venous apertures were open, and what was instantly taken into his depths throttled the man. Virtue can do so much so often to bring death on oneself, and crime so little.

Someone may say that this sort of event should not be taught. But it is more helpful to be taught to take care than it is risky to make matters plain; anyone who is going to do this sort of thing is already sending someone to his death;

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[151] Evidently the poison is not intended to kill the victim, but rather to facilitate her (or his) seduction, on the pattern of what nowadays is termed "date rape" after the drugging of the victim.

[152] "pomum ex opio et mandragorae succo."

[153] Among the works of Ioannes Aurelius Augurello (born 1440 or 1441, died sometime after 1518, a poet in Latin and in Italian) is *Carmen* 23 in Book II; "Charon et Nelphus." The details are not precisely as Cardano sets them down here, but the helmet is smeared inside with hemlock and opium and other soporific items: "Nam cassis intus spongia madet circum / Tetro cicutae uel papaueris succo / Infecta, et aliis, quis inest sopor, rebus." I am indebted to Dr Iain M. Beavan, of Aberdeen University Library, for help with this reference. This sentence first appears in 1560.

[154] "galea."

[155] "cassis."

anyone who has already done this will find many ways to do harm, and it is easier to make some discovery and to collide with the foliage you have noticed in advance[156] than it is to discover nothing at all. So there is more help in teaching than risk in doing this.

But things that have not in themselves been properly discovered, like a poison to kill by touch alone, or by a light odour alone, in the way that people used to arouse the plague by introducing a dust with pieces of cloth, or arouse the noxious power of an unknown herb, disease-like and yet lethal, or a poison that kills over a period of time — this is not sensed at the start, and as a rule anything not open to any discovery, if anyone explains it, is worse than a poison as much as a raging people is worse than a single man. What is the trouble with a people? [646]Is it not displaying itself as the teacher and guide of all criminals?[157] And what makes a poisoner worse than a thief is that it is harder to avoid hidden &1163 [wrongly numbered 1063] traps than obvious ones. So I did not want just to avoid teaching or experiencing such things — I wanted to avoid knowing them, seeing that there is a very rich crop of useful things to which you can apply yourself, even if you live in the ages of the Cumaean Sibyl.[158] But I did not prefer to experience these things as much for the sake of their usefulness as for the sake of investigating them.[159][E] But I return to my theme, and seek after useful things of which the rationale is obscure. It is said that a crayfish placed on a wound draws arrows out. And those who have been anointed with lion fat are surprisingly safe from wild animals, since these take fright at the smell, whether of a living lion or a dead one. This is especially so when you have come face to face without fear; if you take to your heels, they will hardly detect the smell. On a similar basis, it is held that the juice of a "radicula" or radish, if you smear it thoroughly on your hands, makes you able to handle snakes in safety; either they detect the pungency of the smell and are afraid to bite, or are even killed by it. If they try garlic with their teeth, weasels and squirrels hardly dare to bite it subsequently, and in this way get tame. It is beyond belief that the spur of a cock's right foot can make people victorious; or much more incredible, that over eighty days, human blood clots into a human shape, or that if this shape is buried in barley flour for nine days and then its throat is cut, the blood flowing from it and smeared on one's face makes one welcome at royal courts and attractive to

[156] "in praevisam frondem incidere."

[157] "Quid populus? Nonne hoc est sceleratorum omnium hominum exhibere se doctorem ac praeceptorem?" Translation speculative.

[158] The adjective "Cumaea" is feminine, and the Sibyl was the notable Cumaean woman. On Cumae and its Sibyl see n. to Book II at 210 (1560).

[159] The next paragraph and most of the following one are represented in 1554 by different material, such as description of the arrest of haemorrhage and discussion of poisoning.

everyone. What could be more ridiculous?[160] Among less inconsistent marvels, it is on record that wine does not spoil in the Dog days[161] (this normally occurs because of the heat and the thunderstorms), if the vessels themselves are wrapped in the skin of a seal.[162]

&1164 Bewitchments[163] are midway between poisons and tricks; more genuine than the latter, more remarkable than the former. The helpful measures are to be explained before the crimes. It is of use to withhold belief, and to protect oneself with health-giving gemstones. They show that the hatreds of princes are none of them bewitchments. If any are, they consist in rotted food, fouling of clothing, refuse, parts of the human body, imagination.[164] But hippomanes[165] and a puppy's womb are not philtres; that impious Agrippa filled the fourth book of his *Occult Philosophy* with such items, concerned with bewitchments and poisonings—a very vain man, he wrote about the vanity of the sciences.[166] He was in total ignorance about what he condemned, and wrote from ignorance, and if it had been true, it would have done the human race harm. However, what is eaten and touched is ineffectual,[167] but what we imagine is not free of risk. For instance, if anyone suspects human vitals daily, if he paints death ploughing backward.[168] The remainder do no harm, unless from the characteristic of the spell-caster, and the weakness of soul of those against whom these devices are constructed. Consequently such things are not harmful to princes and brave and wise men, but to women and children—and not to all of them, but to the less worthy. And it is not like an honest or straightforward man to be acquainted or enquire about such things, unless someone already keeps his mind so unblemished that he can despise money. But teaching such things is for an assassin.

So moving on from this part—malicious magic, natural though it is—let us move on to useful magic. But beforehand, let us disprove its falsity[169] in some respects: this book contains general counsel, and we have set out the details in

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160 The next ten sentences appear first in 1560.

161 Late July and early August, very hot days when the Dog Star (Sirius) is in the same part of the sky as the Sun.

162 The power of sealskin to protect against lightning is mentioned in Book II at 102 (1560), and also by Marsilio Ficino in *Three Books on Life* (311); and further tales about seals can be found in Book X of the present work at 680 and 754–55 (1560).

163 "veneficia": this word can also mean "poisonings," but since another word for poisons follows at once, "bewitchments" has been used here.

164 φαντασία.

165 See n. 131 above.

166 Heinrich Cornelius Agrippa von Nettesheim (1486–1535), *De incertitudine et vanitate scientiarum* (1527). On him see n. to 937 (1560) in Book XV.

167 or, *not* ineffectual?—simply "irrita sunt" in 1560.

168 "si quis suspicit quotidie medullas humanas, si pingat retrò arantem mortem"; the sense is obscure.

169 "vanitas."

the books *De rerum varietate.*[170] &1165 People say that if a vagina or penis can be measured by a wax candle which has been in a funeral,[171] he or she is prevented from sexual intercourse. So either the male is barred from intercourse with any woman, or just with the woman whose name is employed. If just with her, since nothing belongs to her except words, words will have force beyond people's agreement. If with any woman, then it should be forever (which does not fit experience),[172] or for some specified time. As there is nothing that can stop either the generating of semen or the imagination or the wind[173] by which it is directed, it is clear that this only happens in some people, not always, nor in everyone.

Then, to return to my topic: first of all, people attach significant power to seals: that of the Sun for magistracies, honours, favour with princes; that of Jupiter for riches and friends; of Venus for pleasures; that of Mars for courage; that of Mercury for cunning; that of Saturn for endurance of hard work; that of the Moon for popular favour. And I wish I could know what would be conducive to each. I am aware that stones and the opportunity for sculpture help, and the figure does not do so at all.[174] But maybe while we gaze at the mind (as I said), the figure can change rather more than the stone or the constitution. But I will deal with this elsewhere. It is thought that talc[175] and quenched lime in mallow juice, or a mercurial, can function to stop harm from fire, if the hands are anointed.

If a big toad is killed with salt, and the salt dissolved in water, and an undershirt or shirt is washed in this water, people say that the man who puts it on will be seized with serious itching. &1166 This is either entirely true, or partly so, or is plausible. And[176] I did not miss the case of the woman cured of nephritis by wearing a gold likeness of a lion. But the rationale has to be requested from heaven. Some things do indeed look more true than they are, but some are more true than they look.

Of this final kind is the experience handed down by Boethius, one sufficiently well known, and we have often seen it when at leisure. Take two lyres or similar instruments[177] and place one on its back, already tuned.[178] Then place a

[170] *The Variety of Things.* Completed in 1553; for details see Maclean, *De libris propriis*, M104.

[171] "Dicunt, si vulva aut membrum virile metiatur candela cerea," syntax and hence meaning uncertain. " Metior" is deponent in classical Latin, but the translation assumes Cardano regarded it as passive.

[172] Cardano's own impotence proved not permanent; see n. to Book V at 370 (1560).

[173] "flatus."

[174] The next two sentences appear first in 1560.

[175] "Astrum Samium"; see n. to 368 (1560) in Book V.

[176] The next two sentences here first appear in 1560.

[177] "testudinibusve."

[178] "prius tamen ad concentum nervis extensis remissisque deductam."

piece of straw on the second and first strings of this one that is on its back, and pluck the first string of the other instrument you hold in your hands. As it gives out a sound equal to that in the instrument lying on its back, the straw will at once jump and dance about, as if struck by something; and by shifting part of the straw like this along individual strings, you will convert the instruments to an equal voice—indeed the same one[179]—with wondrous skill.

The explanation of such a marked effect seems to have stayed unknown. Is it because it does not just jump up, when it can emit an equal sound? Or because the air itself, possessing equal power, can do the moving, but not if it is too slack or more stimulated? But even this is not true, since the slacker tension in a thinner string, suited to emit an equal [647]tone, does the moving; an equal tension does not move with an unequal sound. It appears to me that this actually happens because the air in motion always evokes a sound in strings, although not heard. But when the movement is equal, the air cooperates in a single movement—&1167 it is moved on the same basis, and does not make any kind of resistance. So it is conveyed intact to the resting string by the force by which it is moved, and moves with nearly the same size of force as moves it.

Things that are less true than they seem are: for instance a stone that is ignited by spittle. It is made from three pounds of quicklime, three ounces of Greek pitch, and an ounce of lodestone.[180] These are ground up and boiled in an earthenware pot closed with bricks, then buried in laurel oil for fifteen days, then kept in a dry place. This is less credible, because it does not always ignite; but lyre strings brought to equality always move the straw, and yet in the case of this stone, it is better provided with an obvious explanation of its effect.

With many marvels, when you get to know the explanation, all astonishment is over: for instance, sulphur evenly dissolved in wax makes it unquenchable—but the sulphur has to be very pure. Likewise, if a candle coated with sulphur dust and charcoal dust is immersed in water in wintertime, and its upper part is wrapped in paper and it is hung where a drop falls, it will become surrounded by quite thick ice, and then burn on being lit, and the ice will look ablaze to the onlookers, by a great marvel. Thus lyre strings stretched over hot flesh produce an image of worms when they are twisted. Symeon Sethi[181] reports that a lamp wick placed in sepia ink mixed with verdigris, if it is lit without any other light, displays everything present as partly black and partly green. I explained &1168 such things above when I was dealing with light and illumination. And distilled water of capers really makes whiskers and hair green.

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[179] Boethius (Anicius Manlius Severinus Boethius) describes in his *De Musica* (trans. C. M. Bower [New Haven: Yale University Press, 1989], 4. 18 [160–161]) a roughly comparable procedure involving resonance.

[180] "Heracleus lapis," lodestone, the magnetic stone that attracts iron.

[181] On Symeon see n. 51 above.

It is to the point to mention among the real and natural experiments this one, that all fruits are converted into whatever form you wish, especially the larger ones without a stone, such as pears, quinces, pomegranates, cucumbers, gourds, eggplants. This is the technique: fashion the shape you require in wood, the size of the complete fruit; surround it with plaster of Paris dissolved in water, the thickness of the little finger, and divided in two. Dry this shape fast and remove it from the wood; this is easy if you have smeared the wood first with oil. Remove this hollow shape from the plaster of Paris, split it in two, and tie it tightly onto a growing fruit which is more than half the right size. Set this aside till the fruit has reached the right size. You will get a fruit of the form to which the wood was shaped, and you can write what you wish on it; for instance you can truly say, "Grow, and rise up straight, as my claims to fame."[182]

The[183] same experiment succeeds in roots (though not in all of them), on a very different basis.[184] Very large and healthy ones should be taken, such as those of bryony, and those that are woody and long-lasting; and both sorts of turnip and radish can be tried in the same fashion. Bury them, back in the earth, after shaping with a sword, till they have covered the scar. Thus a root changes over from bryony to mandrake, with genitals shaped now into those of a male and now of a female.[185] The bristles of sown grains of barley, so they say, are added &1169 near the root's top, so that the plants may be grafted.

Human bodies are also shaped, by squeezing an infant right from the start with virtual birth figures. But if the purpose is sometimes to mark new shapes, you can easily achieve this in a hot room, by dividing the skin surface with a razor, having previously painted the shape on the skin with ink; then fill up the cracks with cinnabar[186] or a blue or earthy colour that you wish to paint in, and at once, with the colour taken up on account of the heat of the room, the skin coagulates into the image. Otherwise, as I have learnt by trying it, and without a bath: allow cantharides to be mixed for a whole natural day with the water of separation of gold;[187] then mark out on the skin the letters or other shape you wish, in

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[182] "Crescite, et in titulos surgite ritè meos": Ovid, *Ep.* 5. 26. For "ritè" nowadays "recta" is read, and has been translated here.

[183] The next three paragraphs appear first in 1554.

[184] "ratio."

[185] The mandrake root was traditionally regarded as resembling a human figure, with magical powers— e.g. to walk about, and to scream and do deadly harm if uprooted; hence the recommended procedure was to tie a dog to the plant and retreat out of earshot while the dog did the uprooting and suffered any consequences. See also n. to Book VIII at 550 (1560).

[186] On cinnabar see n. to Book II at 137 (1560).

[187] Nitric acid and sulphuric acid can dissolve silver, but not gold, and thus separate gold from any accompanying silver; for use of the term "water of separation" in relation to purification of metals, see for instance Giambattista della Porta (1535–1615), *Natural*

such a way that traces of the water are left behind—white blisters will break out at once in the places the water has occupied. When these have burst spontaneously and been settled for a day, a permanent white scar will follow, and is totally irremovable except by violence; it perfectly reproduces the shape that has been painted in. For this procedure to be clear, I wish to add a few details. Water of separation is indeed actually like that, since it has no need of fire in order to melt silver. Cantharides is an agent capable of ulcerating the skin. It was previously shown that when agents like that in potentiality are combined with those that are like that in actuality, they pass the whole force across to the latter. So water of separation permeated with the powers of cantharides will ulcerate, and will do so at once, because it is of the same sort as cantharides, since they have already stuck to the skin for a long time, and started to act by the power of natural heat.

Then when they have begun to act, they act at once, and this is ἀπόδειξις.[188] You can fatten the lean &1170 bodies of children in the same way, when the flesh has gradually been removed from their skin; the nature of growing leaves nothing empty. In adults too this contributes something; and these things are based on nature.

This is the true metamorphosis of figures; that of substances is another thing, as when we wish to make a Pyrophilus stone. We will allow two pounds of human blood to decay for fifteen days under horse dung. Then we will make a distillation through glass, and keep the extracted water, and dry the sediment in a vessel called a crucible, in which metals are generally melted, by placing charcoal underneath until it passes over into a sort of lime. In addition, we will put this lime in a glass vessel and mix it with the kept water, and on a slow fire convert it into a stone, whether we let it be congealed by the air, like bricks, or while buried. Agrippa[189] describes in his *De veneficiis ac experimentis* how this stone is reddish and bright. I have seen these books linked to the fourth book about the *Occult Philosophy*, and it is entitled, "The practice of what was explained in the previous three," none of which has come out.

The same conversion can [648]occur in plants and in the parts of animals into stones, and on the same principles. Almost the individual kinds of herbs pass across into various species of worms or snakes, endowed with various forms and virtues of their own. And this is what we call the great metamorphosis; as we said previously, since the fatty moistness is separated in putrefaction from the earthy, everything that can rot does rot, &1171 for instance herbs, plant leaves, flesh, eggs, milk, during enclosure in a glass vessel and burial in steaming horse dung. When buried in this way, this sort of thing must excrete its fatty moistness, and when that is removed, a living animal is generated. This generation cannot

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Magick, Book V, 172: "All the dregs of the Gold being now removed, cast it into water of separation, and the Gold will fall to the bottom of the vessel, take it."

[188] The Greek means "a demonstration."

[189] On Agrippa, see n. to 937 (1560) in Book XV.

be prevented, except by burnt waste matter, while there remains an admixture of fatty moistness.[190] There are actually things that are not seen to rot, such as bitter and harsh things—they do not in fact generate an animal, since this goes on so slowly that what fatty moistness is present is exhaled before it is separated. Indeed, all generation, as has been said, consists in separation. Consequently this sort of thing withers away and wastes rather than rotting. Bitter things rot more easily than harsh ones; you will find worms more often in wormwood than in garlic or onions. In fact, not all that is bitter to us is bitter to animals. The authority is the Poet, saying of goats, "and grazing the bitter willows."[191]

And when ginger rots, apart from being fatty, it is also less harsh. Of things that rot, diversity of matter is the explanation for the diverse forms of animal that get generated. Then if things that differ in form differ in species, and things that differ in species, powers and way of life, and that are generated from diverse matter, differ in form, it must be the case that what is generated from diverse matter has diverse powers, as was said previously about wasps, asps, and hornets.

&1172 There are times when various kinds of animal are procreated from the same matter, but with a different efficient cause; for instance, with us drops of water in summer generate fleas; the same things in Darien,[192] a province of the New World, turn at once into toads. So it does not seem ridiculous to me that where someone has spat, small frogs should have turned up instead of the spittle, inside half an hour;[193] we have in fact explained how human nature can imitate anything the nature of air can do. And perhaps it was being aided by some things that had been well chewed, as might be expected from frog ash, or some part of frogs; we have actually shown that in the animals generated from filth, their generation is easy. And that they are generated from their own refuse. A rainstorm indicates a short and speedy generation for them, as they come from moist substance. That is why they are also suitable for those who have wasted away. So it is with less confidence, indeed I can hardly say, "without a miracle," that one might believe that the magicians changed rods into snakes in Pharaoh's presence.[194] So things and districts are endowed with marvellous properties. Chalk does not nourish a poisoned animal, and yet it is warm. The explanation is either that the nourishment is lacking in it, or that the air itself is a bar, because of changes;

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190 The next seven sentences appear first in 1554.

191 Vergil, *Eclogues*, 1. 78.

192 In Panama, in Central America.

193 The next five sentences first appear in 1554.

194 "Sic igitur minore, ne dicam sine miraculo credi potest, magos coram Pharaone virgas vertisse in colubres." The syntax is obscure and the translation is consequently speculative. The event is recorded in Exodus 7: 8–12: the priest Aaron first cast down his rod, which turned into a serpent; Pharaoh's magicians matched this feat, but Aaron's rod then "swallowed up their rods." See also n. 12 above.

good odours are preventative, and are destructive of them.[195] Though there are many more astringent and heating things, rue is outstandingly strengthening for the stomach and all the intestines. Beans corrupt the air in their neighbourhood, though harmless if eaten, indeed, through some property they arrest discharges[196] from the head.[197] And though there may be a different explanation for the fruit, for the plant, and also for the green and the dried fruit, this plant is still not moist enough to &1173 affect the air.

It has been discovered in our regions that silkworms corrupt the air more than beans. These animals (and all the kinds of worm, and locusts) do this because of their waste matter and the smell of fatty moistness; they abound in that, as stated above. But among the pulses beans are themselves rich in it; the evidence is the repeated generation of animals in them. It follows that peas too will be like this. As often said, most things occur from a cause uncertain to one set of people but known to another.[198] Lemon or orange fruits rot very fast from the heat of bread, though less spoiled by many much hotter things;[199] since that heat is moist, it cannot dry, and so causes rot. Hence it is reasonable that bread's heat promotes the decay of everything, but in one case more than another. On a similar basis, some people think it astonishing that madder[200] held in the hand can colour the urine—unaware that cantharides elicits bloody urine, and arouses a burning feeling from it, the two evidently with a shared explanation: that from their heat, such agents induce the hands into activity, and when they are drawn inward, they are drawn from the arterial apertures to the bladder.

So it was more attractive to turn the inquiry to what follows from this. First, as this medicament makes its way in so readily, it must have very rarefied parts. Then, as it makes for the bladder, it must have something in common with the bladder's nature. And that it is only to the bladder that it gets through; if it is linked to anything else, it can very easily convey their power to the bladder, and inside through the whole body. Such a careful search is not just &1174 pretty—it is also useful in many contexts.

To proceed gradually: the explanation of some things is more obscure: for instance, that animals are damaging to vegetables, and are kept away by the

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[195] "odores enim boni prohibent illa, et exitio eis sunt." Syntax obscure; it is not clear what the odours prevent, and cannot on the face of it be the changes, since they are feminine gender; nor is it clear what is destroyed here. 1550 includes here two sentences commending celery for bad breath.

[196] "fluxio"; this word is now regarded as no more than a misreading for "eluvio" in Cicero and Pliny (*L&S*), but Cardano no doubt used texts with the misreading.

[197] The following six sentences appear first in 1554.

[198] "incerta his, illis cognita causa": translation speculative.

[199] Parts of the next ten sentences appear first in 1554.

[200] In addition to the Latin phrase "rubea" (or rubia) "tinctorum," Cardano supplies the Greek equivalent, "Erythrodanum."

water in which crabs[201] have been exposed to the sun for ten days. The younger brother of the King of France used to suffer from a very severe ulcer, of prodigious viciousness; he was cured by a boy in his twelfth year breathing onto it continuously. And this makes good sense: spirit[202] from the heart of a child of established age but before puberty is pure, and can correct corrupt humours. If you mix wheat flour with lizard grease, saltpetre, and cummin, then hens lavishly fed with this food fatten people who eat them so much that they burst.[203] This is in accord with nature, and therefore quite often true. It is one thing to be quite often true, and another to be more true; always what is in accord with nature is more often seen to be true, but not always more so, as in the case of the lodestone. A thing is said to be detached[204] from nature, because its causes are wholly obscure—for instance, that from the direction of a threatening gale, the burnt horn and dung of a buffalo protect, so they say, plants and crops from rust.[205] Here is quite a true discovery of ours: basil juice drunk from half an ounce of it along with a half scruple[206] of saffron does [649]wonders for the breathless and sighers.

I could go on forever on this sort of thing, whose unknown origin provokes astonishment—and not just on plants, animals, and human beings, but as I said, on regions, the soil, waters, and procedures. When sciatica is &1175 very severe, often music is curative. Can it be that this agony is soothed, since it does not affect a main organ, through spirits being transferred from elsewhere for pleasure, and then from what is done[207] the agony's cause is turned away by the heat that is established? Pigeons are lured by the following little cake:[208] maize or sorghum, 60 pounds; cummin, six pounds; honey, ten; costum,[209] one pound, five pounds of chaste tree[210] seed. It is all boiled in water till the water boils away,[211] then a sufficiency of odorous excellent wine is added, with fifteen pounds of old rubble, and make a heap in the middle of the pigeon house. When other pigeons have detected the smell, they come to the place; they detect it too on associat-

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201 "cancri aut paguri."

202 I.e. breath, in this context.

203 "disrumpantur"! Most of the next three sentences appears first in 1554.

204 "remotum."

205 1554 here includes a far-fetched scheme to prevent a woman removing anything from a dish, by putting some basil under it.

206 That is, one forty-eighth part of an ounce; saffron is very costly.

207 "usu."

208 "pastillus."

209 Aromatic plant, *Saussurea lappa*, or its powdered root (*OLD*).

210 "Vitex": chaste tree, or monk's pepper: *Vitex agnus-castus*.

211 "ad illius consumptionem."

ing with the local pigeons; when they have once been there, they cannot leave, enticed by the attraction of the food.[212]

There is greater uncertainty about poisonings that occur (so to speak) without food.[213] In some races, a sacrifice used to occur to the demon Moloch, and when the king had sacrificed his own son in the walls, by this he prevented the Jews capturing the town; among the Romans "Hysteropotmi,"[214] that is, people undergoing the fate of those being born from the womb, since on behalf of them rites would be performed to the gods of the lower world, since they were absent. And unless they made their way in through the roof tiles, they were thought to have ended their lives by violence. The authority for this is Plutarch in his *Questions*; he reports it. That Acteius, the tribune of the plebeians, poured out curses and threatening prayers to the gods below against Marcus Crassus.[215] Among Christians, in place of the prayers and curses that are thought to have destroyed Crassus,[216] there are the instructions of the valley[217] of Iosaphat,[218] by which there was a public ban, and it is thought that the guilty were hounded to death by these &1176 within a year, and those who deny their debts or cannot be coerced on account of their power. These things occur, as I understand, in the district of

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[212] In 1550 material appears here about alarming dreams, a shorter version of the account at 1137 (1560) in the 1554 and 1560 editions. See n. 57.

[213] Food, or *bait*?—"quae sine esca (ut ita dicam) fiunt."

[214] "Men of later Fate"; Plutarch (*Moralia: Roman Questions*, 265; Loeb 4: 15) wrote of Aristinus, who had somehow had his funeral held and his tomb constructed, and then to achieve release from the superstitious dread that then attended him, "chose the part of wisdom, and delivered himself like a newborn babe into the hands of women to be washed, and to be wrapped in swaddling clothes and to be suckled; and all other men in such plight do likewise and they are called 'Men of Later Fate.'" The syntax of this sentence is tortuous and the translation is literal rather than lucid.

[215] "But A*t*eius [not A*c*teius] ran on ahead to the city gate, placed there a blazing brazier, and when Crassus came up, cast incense and libations upon it, and invoked curses which were dreadful and terrifying in themselves, and were reinforced by sundry strange and dreadful gods whom he summoned and called by name" (Plutarch, *Life of Crassus*, 16. 5; Loeb 3: 363).

[216] Crassus in fact died in battle at Carrhae in northern Mesopotamia in 53 B.C., after a whole sequence of ill omens which are described by Plutarch in his *Life of Crassus*.

[217] "vallis." According to the Old Testament prophet Joel (3: 2 and 12), at the valley of Jehoshaphat, once king of Israel, Jehovah intervened against the gentile nations on behalf of the Jews, and subsequent generations of Jews and Christians identified and venerated what they regarded as the spot, which might also be destined to be the site of the Last Judgment. See Jerome, *In Joelem*, PL 25. 979-80; and Flodoard of Reims (PL 135. 473C-494C) in the tenth century composed poetry in honour of its church of the Virgin.

[218] Iosaphat is a variant rendering of the name Jehoshaphat.

Bergamo.[219] Other people have besought help from technique, not from those above; for instance, anyone who puts round a debtor's neck a collar of steel, which no one can remove except the person who put it on. A few years ago our fellow-citizen Zafaronus was tricked by his creditor Vincentinus and died from this misdeed, since Vincentinus had put it on more tightly than he intended.

But I return to curses.[220] Some people light a candle in the home of their enemy, and move it to the nearest church, where they use dreadful curses, and it is thought that our patrician Gaspar Vicomercatus died through this manoeuvre. I will give my view. Fear greatly aids the power of a "veneficium," or the expectation of the person against whom it is directed, and of him who made it, or persists in steady faith—also if something is included entirely in addition to the words "chance" and "fortune." Lastly, there is something occult, which is peculiar not just to the species, but also to this man or another one. I certainly find in Arrian,[221] a reliable historian, in the seventh book of his *De gestis Alexandri*, that before Alexander passed away, Pythagoras[222] the brother of Apollodorus[223] had sacrificed a liver which was found to have no head.[224] This man had come on Alexander sacrificing for Hephaestion,[225] and later for Perdiccas[226] and Antigonus;[227] and to others for Cimon[228]—all of these died at once subsequently.[229] But it is on record that Alexander was warned by the Chaldaeans not

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[219] "ager Bergomensis"; "Bergamensis" is the orthodox spelling. Bergamo is in north-eastern Italy, near Milan.

[220] "veneficia."

[221] Arrian, *Anabasis*, 7. 18. 5.

[222] This Pythagoras was not the celebrated mathematician, but a seer who accompanied Alexander on his campaigns, and not in fact a brother of Apollodorus. When Alexander heard that Apollodorus had made this sacrifice, he required his own seer Pythagoras to tell him the outcome, with the result mentioned here; Alexander found this dismal.

[223] He was the commandant of Babylon, and sacrificed to learn Alexander's fate (Plutarch, *Alexander*, 73. 2).

[224] It lacked lobes (Arrian, *Anabasis*, 7. 4; Loeb 2: 267: ἄλοβον τὸ ἧπαρ ἐγένετο).

[225] A Macedonian noble (c. 356–324 B.C.), the closest companion of Alexander the Great, who died suddenly.

[226] Another notable close companion of Alexander, who survived him, and briefly attempted to take over his leadership.

[227] Antigonus I was the son of Philip of Macedon and held a distinguished command in Alexander's army. He too set out after Alexander's death to unite Alexander's empire under himself, with much success, but he was killed in battle in 301 B.C.

[228] There appears to be some confusion: no one of this name appears in the Arrian account (*Anabasis*, 7. 18; nor elsewhere in that work).

[229] 1550 and 1554 include here a cryptic sentence about the heart of Caesar the dictator at his death.

to enter Babylon, &1177 since this would become the end of him. So when he entered, he left at once, and examined the Pollacopa ditch of the Euphrates.[230]

But there are people who say that these prophets devised this prediction by deceit, because they were guilty of receiving substantial bribes.[231] There are also in ourselves traces of future events in our nails and even in our teeth. In some cases these spots show the outcomes, in others merely empty hopes; but according to the nature of the hand and of the fingers in which they are found, and their colours and their alteration. In the thumb: honours and pleasures; in the index finger, profits; in the little finger, concerning minor business; in the middle one, thoughts and tasks; in the ring one, honour. Black spots overthrow, and presage disasters, white ones strokes of luck—large ones mean large strokes, shiny ones obvious strokes, little ones little strokes. Dim strokes of luck diminish disasters, and sometimes even increase them. For the elderly and those less capable, hopes are promised instead of deeds. Black spots mean fears, but not so often groundless ones, just as white ones mean hopes; human nature is more inclined to evil than to good. And different stages in life, and diseases, can prevent good and arouse evil. But when it has shone bright, it offers something more than hope or fear: the right hand from diligence, the left one from good luck, unless anyone has a rather strong left hand. It is time for a start when spots appear at the root of a nail, and for an outcome when they reach the end. This makes the difference between hope and fear for the outcome, because as these spots advance, they are more obvious, and grow, but others shrink and vanish. The time of turnover of the &1178 whole portion of a nail that is seen is from three to six months;[232] it is hard to estimate for the whole nail, but in my view it can reach a year.

The part of teeth (that is, the one that protrudes from the gum) changes over a period of about seven years, but the whole tooth takes about twelve, or a little less. But this is not fully agreed, nor does it matter. I have observed this too in women, a mother, and a daughter. The mother had an S trace, the daughter one like an O; both white, indeed snowy white; from the exit from the gum it vanished all round as the tooth wore away, and around six years elapsed; then she married a distinguished young man, though she herself was poor.

In some cases hopes and in some effects are promised, and quite quickly or quite slowly: for instance, a mother acquired quite a distinguished husband, her

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[230] This was a canal from the Euphrates, not a branch of that river. Arrian (*Anabasis*, 7. 21; Loeb 2: 277 onward) describes its manipulation for agricultural purposes prior to Alexander's time, and Alexander contemplated closing its outlet, but did not proceed.

[231] 1550 includes here brief reference to the work on divination of Artesius (Longaevus), an obscure mystical writer mentioned for instance together with Hermes Trismegistos in an English work of 1692 (see A. Bregman, "Alligation Alternate and the Composition of Medicine: Arithmetic and Medicine in Early Modern England," *Medical History* 49 [2005]: 209–320).

[232] In the 1554 edition, four to seven months.

daughter only a hope. This makes clear that nail growth is due to the Moon, but tooth growth to the Sun. So this observation is not superstition. But it is due to the same causes that aid us and our affairs (that is, the Sun and Moon) that these traces happen. And they appear especially in these parts, because they are more easily [650]imprinted there, because of their brilliance and transparency; it is certain that those to whom such things happen have a soul extremely crafty and wise, as was said about these women. Spots on the teeth are more indicative[233] in regard to nature, because they are related to the Sun, just as those on the nails are more indicative in regard to fortune, because they are related to the Moon. To my own observation, this appeared more true than another kind of augury, and was of considerable help; divination appears to be of &1179 as much help as fate permits.[234] [C] And there are significant tricks in this field: for instance, people who write on an egg, and what they intend appears inside, because the shell is permeable, and lets colours pass. Knead in vinegar oak galls ground up with alum, and then write on the shell what you wish with this liquid, and when it is dry, place it in brine. Or smear the egg with wax, and write upon it the letters with a stylus so that the wax gapes and the wax smears remain on which the liquid[235] can be placed. Boil the dry egg till it hardens, then immerse it in strong vinegar; in this way the letters get to penetrate, and you will see them on the egg when the shell is removed. For vinegar softens the eggshell, so that it can be put in a narrow jug, but water hardens it.[236]

If I append the explanation of these two tests I have made, I have made the issue worth handling, and will open a route to the discovery of other tests of this kind. The softening of the shell by the power of vinegar occurs because as the Greeks put it, it has pores;[237] it sweats, so it absorbs the vinegar. Vinegar is of rarefied substance, and so it makes its way into the shell's substance. Since the eggshell is composed of coldness, and is of tender substance, it will be dissolved by moistness. But because of its excessive coldness, water squeezes out the content of rarefied moistness in the substance, and coagulates the rest; thus an eggshell that had turned out soft in vinegar is hardened in water. So when you have kneaded oak galls and alum in vinegar, the vinegar acquires the power of each, and hence when the letters have been written, the vinegar makes its way inside through the passages of the shell.

In the white of an egg, an oak gall leaves behind a dull saffron[238] colour. But alum &1180 prevents it being affected by fire; so the colour will stick quite

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233 "pollicentur."

234 In the 1554 edition here Cardano remarks that he has included in his *De rerum varietate* all of Aristotle's contributions to divination.

235 "humor."

236 The next three paragraphs first appear in 1554.

237 Πόρος means "a way through," in many senses, including that here.

238 "Subcroceus."

strongly, as if it were dried in brine; the shape of the letters will get established. Then it is immersed in strong vinegar, either so as to transfer what was preserved by the brine from the shell more to the white of the egg, or else, if it was boiled down in a fire, it draws inside the residue remaining in the shell. In fact it comes about through the primary power of the vinegar that the design makes its way into the shell, but not that the greater part entirely makes its way to the eggwhite, because of the scarcity of vinegar.

Secondly, the design is transferred to the surface of the eggwhite. For everything that is a participant in an action receives an image from what is in action, and transfers it, if it does not corrupt it. The designs are already in action through the fire on the shell, and the pungent vinegar is in action; in fact, as has been shown, it dissolves the eggshell without heat; so the vinegar conveys the image of the letters, and obliterates those on the shell, so that they are invisible. So when you have taken the shell off, or someone else unwisely boils the egg again, with the images retained because of the alum's power, the letters will appear conspicuous when the shell is taken off.

Let us leave this, and return to genuine visions. These are of three kinds: some during sleep, some in a trance, some in simple wakefulness. I shall add examples of these. In sleep, I have been urged more than once to write this book, and as it appeared to me, to write it divided into 21 parts; the themes were diverse, and around the middle, some scraps of geometry. Then throughout, diverse novel discussions, quite refined, and with true subjects;[239] with more than ordinary lucidity of language, combined with &1181 some welcome obscurity; and then the continuity of the style and the subtlety of the reasoning made the project look virtually divine to me, so much so that in my sleep I was overwhelmed by so much pleasure that I have never felt its like. I seemed to be carried out of my senses, and after the sleep, even the recollection of this pleasure used to afford me marvellous delight. I could recognise the material, which would cover everything, and the book's name, a slim and beautiful mark. The book seemed printed at some distance, and with few copies in the town.

Three features are not in keeping: the book used to seem someone else's, not mine; its size was much bigger, and its style more refined than mine. Perhaps some day this will get changed for the better, or as occurs in mirrors, the same book will happen to appear, but on a different plan, bigger, more handsome, and with its order altered, for instance because dreaming magnifies some things and diminishes others; in fact it increases the guise[240] of pains that have not yet started, but diminishes that of diseases which are already making us suffer.[241]

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239 "rebus veris."

240 "species."

241 In the 1550 edition Cardano speculates briefly here on whether some successor will improve the book; any pleasure in this would be for the powers above to grant. And

So when this had often happened to me, I started the little book with four sheets of paper at the outset; later I increased it to seven, then to 35. And never in the meantime did those same images cease, nor that pleasure that I used to feel while reading in sleep; but the more rarely it came back into a dream, the more the book kept growing. It grew later to 57 sheets, and finally to 76, and then was published for the first time with a table[242] added.[243] But when it was visibly half the size of the one that was shown to me in my dream, I thought it was for completion by someone else elsewhere. For the same book had already been printed three times, at Nuremberg first,[244] &1182 then at Lyon,[245] and finally at Paris.[246] But when I had happened on Galen's words[247] in which the way to finish books is set out, I took up the thread again, and completed it to the standard of this way, adding nearly as much as there had been in the first edition, and was assisted by nearly the resources that I applied finally in the preceding book. The total increase amounts to fifty-six pages, and the whole book to 132. Then with the illustrations added, I reckon it differs little at all from the one I saw during repose. But I cannot increase it even if I want to, firstly because the sequence is complete, and then because it would be necessary to consider the whole thing from the start, which for me now would be not just inconvenient but impossible.

But if there are attached to it the three books *De rerum varietate*, which are on the same theme,[248] then the font[249] and the book's size and the place where the [651]mathematical figures appear (not in the middle at present, but at the heel of the book) will almost exactly conform to my dream; Pliny's *Natural History* appeared to match in size the volume that I used to read during repose.

Furthermore, in this final correction, 37 months were consumed—one month more than three years. Such great power do dreams have for some people. But to me these do not look like dreams, but something greater. For instance,

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all the final details of publication that follow in five paragraphs here are inevitably much restricted in that edition.

242 "tabula."

243 Cardano is presumably writing from memory; elsewhere (Maclean, *De libris propriis*, 263) he lists the pages as one to start with, then four, then seven, then fifty, then eighty for publication.

244 By the publisher Joannes Petreius, in 1550; see Maclean, *De libris propriis*, 85.

245 Published by Philibert Rollet for Guillaume Rouillé, 1550.

246 Published by Michaelis Fezendat and Roberti Granjon, 1550.

247 Professor Vivian Nutton suggests that the passage in question here is in Galen's treatise *Methodus Medendi* (Book 7. 1; K. 10: 456 onward) and relates to how he finished this work, though not actually telling how to do it. It opens with an explanation that Galen is resuming the work after a long intermission, to give himself useful stimulation and to store a resource against the oblivion of old age; there is "an almost seamless transition between the end of VI and VII. 2."

248 "argumentum."

249 "character."

the dream that urged me on to write, and I got an account of it engraved on the back of our copper plates.[250] And the one in which I saw the death of my friend Alciatus[251] a few days &1183 before he died. And the one in which I appeared to be in heaven after my death, and in which the books *De rerum varietate* were shown to me.

But these are features of our race, and acquired from both parents by right of heredity: on the night before the following day, the day on which he was attacked by the plague, my father was warned by a dream that on the following morning the plague would assault him. Neither bars nor bolts have succeeded in avoiding the prediction of a dream. And when my mother had two sons out of six (not counting myself) surviving, on the night when they started to be ill, before they were complaining, she saw both snatched from her and reaching the heavenly regions; and the outcome did not prove false, for though they were children, both of them made their way over to the heavenly mansions in the eighth night after her dream and the onset of the disease. We have written ten books about dreams.[252] All I would like to add is this, that people should know there is something in us apart from ourselves. I mean, in all human beings. It stimulates to virtues those who[253] wish, but others to slaughter and poisonings. What do you make of a criminal's mind? Is there someone there on his own? Are there terrors, hates, suspicions, rages, and mental torments, so that when someone has given himself into their power, he cannot be responsible for himself? Seeds are buried in individual instances, and a shoot of the opposing party.[254] Hence no one can be stimulated to virtue, nor to test the veracity of dreams, who covers up and buries what is in himself in addition to himself.[255] There are three groups: of evil demons, of clear light, and of pleasure. And the groups of demons and of the light are more like each other than the group of those who are avid &1184 just for profit—they make their start entirely from flesh and bodily clothing. Consequently even criminals receive true dreams, and foresight of the future, and

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[250] "à tergo aerearum nostrarum imaginum insculpi feci." My interpretation, that Cardano had engraving done on the back of plates for the printing of this book, is far-fetched, but perhaps not in the world he inhabited.

[251] Nenci (659, n. 126) mentions that Andrea Alciati (1492–1550) was for some years professor at Pavia (1533–1537 and 1541–1542). He was Cardano's "staunchest friend there" (Eckman, *Jerome Cardan*, 48), and the great jurist of his age, a very early exponent of Roman law. Cardano wrote a biography of him (*Vita Alciati*; *OO* 9: 569–70 [a brief biography, but not unappreciative: "memoria fuit incredibili, ac tenacissima, ingenio acutissimo, iudicio, et suauitate morum adhuc longè melior, sed nulla in re tam excelliuit, quam prudentia"]; Maclean, *De libris propriis*, 107, in M138).

[252] *De somniis libri decem*—later reduced to *Somnium Synesiorum, omnis generis insomnia explicantes libri IIII*. For details see Maclean, *De libris propriis*, 61–62.

[253] Reading "qui" though 1560 reads "quia."

[254] "adversae factionis."

[255] "quod in se est praeter se."

marvels; a demon, with no body, has something in common with light, but with absolutely nothing else. I know an objection that can be made to me: that I wish to appear divine. Do they think me so stupid that in the eyes of men I would not know this would be attributed to vanity, rather than to my credit?[256] But I cannot keep silent about what I have seen and know, even in the face of great peril. It is of great assistance to me that when the same happened to Galen, the same fear, the same suspicion that he admits he knew well, he still preferred to comply with commands, and not to hide what he knew and sacrifice his credit, rather than pursue popular repute. Anyone who does not belong in a flock of sheep could not judge what difference it makes not to touch flesh.[257]

But if anyone possibly suspects that out of this I am after the reputation of being a saint, he should know that none of the ancients so steadily asserts the death of our minds[258] as Galen, and that we are sinners,[259] so that the explanation of this needs to be drawn from elsewhere; hence these are issues for the books *De arcanis aeternitatis*[260] and *De fato*,[261] not for the present discussion, and are not appropriate for it.

But what is appropriate for this treatise is why a dream displays a much longer time than it actually occupies; on some occasion, in a single hour I appeared to go from Milan to some unknown town 300 miles away—and meantime to travel through other towns,[262] and &1185 so many mountains, valleys, plains, that you could hardly traverse them in six days; and this made me think I had slept a good deal, but the sound of the bells was informing me that I had not met nature's need for even a whole hour. The reason is that the activities are performed without bodily exertion, and hence very rapidly; the judgment is derived by reckoning the time of bodily labour on a scale impaired during sleep. Hence those who imagine such things while awake do not increase the time, recognising that these events have not really gone on, but only been conceived mentally, a fast process. Contrariwise, time is shortened during sleep, since either we do

256 "Ita me excordem putant, vt apud homines hoc mihi potiùs, non vanitati ascribendum esse sciam, quàm laudi?"—the apparent sense has been translated, not the disordered syntax.

257 "Qui non est ex ouibus, non iudicet quantum referat carnem non attingere." Source of this sentence not traced; it is not in Erasmus's *Adages*; but cf. John 10: 26.

258 "animorum."

259 "peccatores"; but for Galen the word does not have the guilty implications of "sin." He does remark that we all err, though fancying we don't (*De cognoscendis curandisque animi morbis*, 2; K. 5: 3), and wrote a whole treatise on the topic (*De cuiusque animi peccatorum dignotione atque medela*; K. 5: 58–103).

260 On this work *On the Secrets of Eternity* see n. to Book I at 5 (1560).

261 See n. to Book VII at 470 (1560).

262 Reading "urbes alias" with 1554, not the "urbem alias" of 1560.

not dream, or dream only a little, and without moving; the measure is the time of motion.

But what is time ?—though nothing of it ever exists, yet everything exists in it, and it is always present along with everyone.[263] It too generates everything and kills off everything—responsible for life and death. And just as waiting for it takes very long, so the memory of it is very short. And though it always accompanies us, we still never recognise it. And though there is such a good supply of it, still no replacement of it is granted; hence the wasting of no other thing is greater nor more contemptible. I have been helped by being well aware of this; but some of it suits that context, some those that are most closely linked to it. For it is worth marvelling that something nonexistent should move along so far.

So we grasp not time itself, but what is in it and is done and continues. In itself, time is unknown to the senses; what is known to us exists in the imagination. &1186 So marvels are represented not just in dreams, but also during wakefulness. And there is a triple condition here: one is in the middle, as in a trance. It once befell Andreas Osiander (a man very learned in every sort of literature, citizen of Nuremberg, theologian, friend of mine),[264] as he indicated to me elsewhere by letter, that when he was an adolescent and was suffering from a quartan fever, during the time of the onset he seemed to be in a wood, and was the target of wild beasts and snakes of various kinds, which was very distressing to him, and he could not be convinced that he was at home, nor that this was mere imagination. But on his father's arrival, at once he started resuming his original state of mind, and recognising his home, bedroom, and friends at hand, without any terror. Yet when his father was leaving, those appearances starting flitting before his eyes again, and all the phantoms were on their way back—and this trouble continued as long as the fever, which upset him for a long time.

I think this is for the most part just like what [652]appeared long ago to those living in a desert; I accept that some things are introduced by God or by demons into saints, things which were at the time calling to mind demons or God. Though these things do happen to many others, they cannot be blamed[265] on God or on demons, especially since they say they can call anything they wish to mind through the imagination, even against our will. And I would not believe that so many reputable people, after a life spent in such intense labour and in solitude, would lie for such a small reason. But solitude in itself and a mind sick with labour and fasting, and a temperament altered by country food, used to illustrate the &1187 power of the melancholic humour in this.

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[263] "omnibus assistit."

[264] Osiander's life span was 1498–1552; Cardano has aptly summarised the key characteristics of this notable figure of the Lutheran Reformation.

[265] "transferre."

There is a second sort of wakefulness, in which only the soul's functioning[266] is impaired, and its power persists; I think it was this kind that I recall happened to me for three years together. This was from my fourth year to my seventh, always from the second hour of the day till the fourth, or if I got up or woke up later: I used to see figures from the end of the bed, as if consisting of little airy rings—figures of trees, beasts, people, villages, lines of battle drawn up, military and musical instruments, and other items of this sort—figures going up and down, with one following upon another. And since as a lad I was extremely delighted with these, and kept looking keenly on, my mother Clara and Margareta my paternal aunt sometimes asked me searchingly whether I was seeing anything. But though I was quite small, I was aware that this was some appearance, which made me steadily say No, afraid that if I had revealed it, the show would leave me, or some mishap would befall me because of disclosing a secret.[267] I am aware that Galen[268] attributes these figures to a subtlety of sensation as their explanation—but not these, which as long as they persisted and recurred in a definite order, would also display such perfect forms.

I shall now reveal the explanation according to Averroes:[269] when seven years had passed, and my home had been changed at the same time, such appearances entirely left me. In his *Collectanea*, Averroes appears to me to put the explanation very prettily, as follows: "When the spirit, in the service of the imagination, has received forms by imagining, of a &1188 sound or of some quality so as to be recognised by smell or touch, either of a dead person or a demon, and the spirit permeated with this quality is passed on to sensation, which corresponds in action, in the case of odours to the specific instrument of smell, in hearing to the ears, in sights to the eyes, it will have to smell or hear or see, with no object present; for if vision is nothing other than the perception of a species by spirit in the crystalloid,[270] whether this species is delineated by the object or not, clearly whenever this happens, a person is genuinely seeing."[271]

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266 "operatio."

267 The following sentence replaces one in the 1550 edition citing a remark of Aristotle about people fainting on witnessing a hanging.

268 Reference not traced.

269 One of the most famous of the mediaeval Islamic philosophers, born in Córdoba, Southern Spain, a judge successively at Córdoba, Seville, and in Morocco; his *Commentaries on Aristotle* were his most important works.

270 The crystalline humour inside the eyeball.

271 "Cum spiritus imaginationi seruiens, formas imaginando exceperit, soni aut qualitatis cuiuspiam, quo odore aut tactus dignoscatur, aut mortui vel daemonis, illáque imbutus transferatur ad sensum, qui ei actioni correspondet, in odoribus quidem ad instrumentum proprium olfactus, in auditu ad aures, in spectris ad oculos, necessariò olfaciet, aut audiet, aut videbit nullo assistente obiecto: nam si visio nihil aliud est, quàm speciei à spiritu in crystalloide perceptio, seu species illa ab obiecto decidatur, seu non,

And so during wakefulness it does happen that one sees demons and dead people, and also hears the voices of one's acquaintances, and senses their odours, and touches them, as in the case of succubi and incubi.[272] This is why these things are seen less commonly than being heard or touched—in the case of the other senses, since it is enough to have noticed a single distinguishing feature, a single spirit transferred to sensation can represent this with that figure, but since in the eyes more distinguishing features are required, size, form, colour, and more spirits need to be transferred. Consequently too nature made the nerves that lead to the eyes hollow,[273] and they are the only ones like that, because in their functions they need far more numerous spirits. And so this makes us much more tired through gazing keenly that by using any of the other senses.[274]

So from this the answer to many problems emerges, and though they are very true, they still so exhaust most people that they do not hesitate to transfer them to the category of miracles, or some people transfer them to demons, and some deny them. For example, something that occurred in Iceland, an island beyond the British, and near Norway (&1189 I do not worry at the moment whether it is Thule,[275] or some other island): people say that they are seeing dead servants, and suppose they are embracing, and that amidst their embraces they vanish. This island is all full of pitch, and even now the human beings live on apples, roots, fish meal, and water, since as it lies in an icy sea, the vast cold makes the maintenance of crops (much less of wine) impossible. Hence their spirits are very thick because of the food, and the air is too, because of the soil and the cold. On account of the thickness of the air, and the vapours congealed with cold, phantoms wander about just as on clouds, and being conceived through error, fear, and thought, they are retained by dense and earthy spirit, to such an extent that this spirit is conveyed to the instrument of the senses. Then the inhabit-

patet quotiescunque contigerit hoc, illum videre verè." This quotation cannot yet be identified in the *Collectanea* of Averrhoes.

[272] Imaginary demonic beings supposed to have sex with humans in their sleep: incubi (male) with women, succubi (female) with men.

[273] That the optic nerves were hollow was Galen's view (*De plac. Hippoc. et Platonis*, 7, 5; K. 5: 618–20), following Plato. And being an experimental scientist, he says he pushed a bristle into the lumen to confirm this (*De Anatomicis Administrationibus*, 14, 2; trans. Duckworth, 187); it is not true in man. Fernel, a near contemporary of Cardano, agreed with Galen (*Physiologia*, trans. Forrester, 23). But Vesalius (*De humani corporis fabrica*, IV, cap. 4, 324) could not find the lumen in the human cadaver, nor could Argenterius (1513–1572), who noted that some spirit goes to the pupil via the *arteries*, not the optic nerves, which are not hollow though they are soft (Argenterius, *Comment. II De Signis*, in *Opera*, col. 282B).

[274] The next four paragraphs first appear in 1554.

[275] An island in the far North mentioned by Virgil, Pliny, Tacitus, and others, but its identity is confused even among their accounts (*OCD*).

ants persuade themselves that these are visible and they address them.[276] They consider that they see well-known dead people, because they know that there are no living ones there, and because they vanish in an embrace—no one has contrived for himself an unknown figure in the clouds, like that of a Chimera or a Hippocentaur. All the transfer[277] is to known things.

But why do these spectres reply that they are on their way to Mount Hecla?[278] Hecla is a mountain in that island, and burns at intervals just as Aetna in Sicily does. Thus from a long held conviction that souls are being expiated there, some people avoid futility by contriving empty material so as to fit the fable. The sorts of thing that usually happen there occur not just in Iceland, but everywhere, though not often. During the past year, the funeral cortege of a plebeian of Milan was being conveyed out at the eastern gate of Milan, near a large church in a shopping square, which from the many cabbages there is spoken of as "Cabbage"[279] in our language. An acquaintance of mine comes up; &c1190 I ask, as physicians do, from what disease the death occurred. He replies that the man usually returned home from his work at the third hour of the night. He saw a ghost[280] one night following him, and when he tried to escape it, he was going off a a run. But the ghost caught him, and he was seen thrown to the earth; he was struggling to shout out, but could not. In the end, after being rolled on the ground for some time along with a ghost,[281] he was found by some passers-by, and carried home half dead. When he came round, he was questioned, and related this account, which was less than what was expected. So giving up hope of his soul, and incapable of being persuaded by his friends or the physicians or the priests that this tale was unfounded, he died in eight days. I heard afterwards from other people too who were his neighbours that no one wounded by an enemy has so steadily testified about his assailant as this man testified that he had [653]been rolled on the ground by a dead man.

When people asked him what he did after they had been rolled onto the ground, he replied that the dead man grasped his throat so as to strangle him. He had offered no resistance, except to protect himself with his hands. When other people queried whether he had happened to suffer this from a living man, and asked in what features he could distinguish the dead man from a living one, his explanation was very reasonable: he said that he handled him like a mattress, and he had no weight, except for being pressed upon.

276 "Inde videri, et alloqui sibi eas persuadent."—syntax obscure.
277 "translatio."
278 The most active volcano of Iceland.
279 "caulis."
280 "lemur."
281 "cum larva."

The world is large, and time[282] long, and error and fear affect people a great deal. On the same pattern as in Iceland, where the Sun blazes in the desert wildernesses of Egypt, Ethiopia, and India, the same figures and &1191 spectres often sport with travellers. I have known many people who have had such encounters, but I have described them in their own place. On a similar pattern, things inaudible and invisible disturb the women who are commonly called vampires,[283] even when they are awake; they feed on chestnuts and roots and water, and inhabit sites in valleys where the air is extremely turbulent. Aristotle mentions that there are people of the same kind who faint[284] because they have seen others hanged.

This makes clear why it is a deadly sign in the sick if in delirium they even see dead people; it signals an imagination so powerful that the spirit transferred to the eye retains the species it acquired from the imagination. But this can only happen with them for instance asleep and with silent senses, or weakened through overpowering illness, or through a strong power of thought and imagination. So since they are not asleep, nor can imagine anything keenly through weakness, what remains for us to state is the only option: that their whole sensitive power[285] lies at its ease through feebleness. This same man explained elsewhere that this means the imminence of death, by expressing the following opinion: when an invalid fails to see or hear, with weak power,[286] death is already at hand.

There is a further point in the present account: that tough men rarely or never see spectres, because themselves they barely imagine such frightening things through fear; more than all other emotions,[287] it creates lasting images in us; next comes love. Hence these are firstly the prerogatives &1192 of the frightened, and secondly of lovers. But do very tough cannibals see nocturnal monsters? It is a failing of regions and of pointless cruelty, when even others there who refrain from hurting people still see such sights. Indeed, the Scythians, who slaughter human beings as a sacrifice, are tough by nature and in their practices, and so see no dead people nor ghosts.[288] Nor do thieves; these evils do not appear to be so by nature, since fishes eat other fish of their own kind, so do mice and other animals, but they are evils by the law of nations. And if these evils existed by nature (that is, against the laws of nature, since after death nothing survives except the intellect, and it could not evoke a movement), the dead will not be able to put any apparitions on view, nor inflict terror on the living.

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[282] "aevum."

[283] "strigas."

[284] "animo defecisse"—could alternatively mean "die." Reference not traced.

[285] "virtus."

[286] "virtus."

[287] "affectus."

[288] "lemures."

The third kind of wakefulness is pure and simple, but marvels happen to be seen in it in numerous ways; for example, when an echo resonates, so that sometimes sounds bounce seven times. This is startling by night, and unless it were well known, could terrorise anyone; it sometimes makes the sounds very clear and delayed. The explanation is that the air is reflected from plane surfaces and cavities; but it does not echo unless there are caverns or walls; it echoes from ancient ones, and more from a distance than close up. The voice has to be blurred in an echo and be reflected from an intermediate plane surface, and it is better reproduced at a high place and in a straight line.[289] If it is night and there is a breeze, the resonance is so clear that when a friend of mine was journeying beside a river and did not know the ford, he started calling out, "Oh!" There happened to be an echo there—he hears the "Oh!" &1193 Supposing it was a person, he asks it where the place is where he can get across, and hears, "Across?" The reply goes better in Italian: "Unde debo passà? Passà?"[290] Then he shouted, "Qui," and the answer came, "Qui."—that is, "Here," "Here." But there was a whirlpool there, and the waters were making an extraordinary din; he was terrified, and asked again in Italian, "Debo passà qui?" Echo replied, "Passà qui." Since he asked quite often, it kept replying in these words. My friend was poised beween fear and necessity and astonishment, since he had to make the journey, the night was dark, he could hear it urging him to cross, as he supposed, where the current's rush was greatest, failing to notice from its accent that it was an echo—when he said, "Debo passà," it comes out with a grave accent, and if a person had replied, the reply would have had an acute accent like this: "Pássa." But as it was an echo, it came back with a grave accent, which he had heard. So as it was dead of night, Augustinus Lavizarius of Como turned back; that was his name, and that the home town of my friend, who was in the confidence of his Prince, and on the books of the Senate.

When after some days he told me in my youth that he had almost been hurled into the torrent by a demon's persuasion, I began to enquire quite carefully how,[291] recognising the man's sincerity and honesty, and finally grasped that it had been an echo, by which he had been misled, while in considerable danger and with his mind churning a great deal.

Though they are numerous, echoes are nowhere more common or distinct than at Pavia. From a number, let an account of two more celebrated ones suffice. The one is near the church of St Paul outside the walls, which is heard at the same time as the voice itself; an echo &1194 is authenticated by three features: it replies quickly, it reproduces a long series of words and completely, and it repeats

[289] The material from here to [D] below at 1194 (1560) first appears in 1554.
[290] "Where am I to cross?"
[291] "modum."

the same thing quite often with the sound falling away.[292] It commonly leaves out the first syllable, because it is masked by the following sound; thus it comes about that contrariwise the final syllable is heard best. The syllable most precisely in a straight line is stifled, hence not everyone receives it from the same place. And not too close up, since by returning so fast it is masked by the actual voice, of which it is the image. And not in a confined space, where air movement leads to confusion. Echoing is done better by aged walls, not just because they are dry, but also because of the air held within them; the contained air imitates the image of a drum. And dryness is to sound what brightness is to light and to the images in mirrors; in the clarity of the voice, and the speed of response, this dryness is so remarkable that any listener stops being surprised that our friend thought himself the plaything of a demon.

It is returned by a section of old wall around twenty palms in [654]length[293] and a little less in height. Another one at the same place echoes obliquely from the wall of an enclosure of wild beasts which is called Barcum, and I noticed it return ten distinct voices from a blast on a horn.[294] Thus nothing can be perfect from every direction. The first was returned exactly, completely and at once, but not more nor more often; the next more, but not more often nor so promptly. The third is multiple—and in the same town, [D] which some people call Ticinium from the Ticino river, in the great basilica (the Italians call it Salam) there is one that beside the city's citadel returns voices from its door so often that they are uncountable; at times a thirteenth &1195 voice is audible; there were many witnesses, and among the rest a distinguished professor of the art of medicine, Melchior Malheuser the German, a pupil of ours. You would think you were receiving a reply from someone, or were deluded—the voices die away gradually, and stop. Hence "Ahime,"[295] which has the sound of "heu"[296] in Latin, is returned like the voice of someone dying and fading away. This church is square, and has many open windows, and is lit in the upper parts from the sides. But the front and the wall opposite it are intact, except for a door in the front. The length is around 100 feet, the width about 25, the height I suppose half as much again as the width (it is in fact tall)—I chose to describe this quite carefully, so that anyone who wanted would know where to develop an explanation and seek a pattern. A manifold voice echoes, if you are standing beside the other wall opposite the door, and it seems to return from the top part of the door at the time. And so a voice resonates from both sides, and especially for people standing outside the door itself, but not in the middle. Hence there is no doubt that it is either a

[292] This sounds like an echo from two surfaces facing each other, with the speaker in between.

[293] On the dimensions of a palm, see n. at 1080 foot (1560) in Book XVII.

[294] "pulsante cornu."

[295] The modern Italian word for "alas."

[296] In English, "alas."

demon or a piece of trickery;[297] an echo is hardly credible, all the voices are heard so clearly, rapidly, often and in a definite order. I heard this from people present: the arch of a portico from the neighbourhood was once placed before the door, and a good deal of it survives. The normal voices were returned much better to those standing outside the door, under the arch, and more richly and with greater gain, so as to resound thirty times upon occasion. It is certainly produced faster, and louder and with a more concentrated voice, and thus is rendered clearer and more repeated. &1196 This[298] happens to it just like the multiple reflection of visual images. So an echo can be called "reflected," though its explanation is less clear.

There are other circumstances that commonly mislead us, but in another way: if indeed an echo and mirrors were rarely encountered, who would not be astounded, since these deserve it as much as others of rare occurrence? But rarity on its own commonly begets astonishment. For an infant to speak, though only recently born, is natural, and yet is reckoned a portent, for being rare, and is always thought a very great one. Aristotle explains how this can be natural: since speech depends on strength of tongue and on intelligence, and intelligence arrives in most cases before strength of tongue, the result is that speech with incomplete intelligence appears a marvel. Yet if strength of tongue is completed first, when a human being is prepared by nature for speaking, why does the human being not repeat[299] what is heard but not understood, as in the case of the woodpecker and parrot? Is this in order that by some effort and assembling of spirits, it can present what is now understood to the tongue? The evidence is that this happens to them especially through sleep, and more clearly, for then what is seen and heard during sleep does more moving, and there is greater profusion of spirits, and from its prolonged rest the tongue has become sturdier. So the astonishment occurs either because the occurrence is rare, or its cause unknown, or for both reasons. It quite often occurs that the rarity of an effect accounts for the ignorance of its cause. Some things are uncommon, so that these are uncommon for the species, those for the genus; for instance, the cat's pupil, which is sometimes seen to be boat-shaped, and sometimes with the figure of a half-Moon, but at other times has an even narrower shape, since this &1197 creature contracts and dilates its iris[300] diversely, but its corneal tunic is very thick. This is why if you examine it

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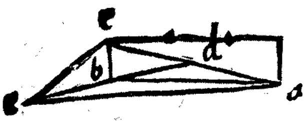
[297] "sycophantia." The account in 1550 differs in minor detail from that of the later editions.

[298] The following eleven sentences, up to the mention of the cat's pupil, appear first in 1554.

[299] "non referat."

[300] "uvea," a medieval Latin word referring to a whole "coat" of the eyeball; Vesalius (once) uses the word "iris" as we do, referring to the coloured disk forming the front part of the more extensive uvea, which in the cat behaves as described here. Fernel in his *Physiologia* (trans. Forrester, 115) remarks that "the uvea has an opening in the middle in

largely from the side, it looks multiform, but from straight ahead more rounded, as in ourselves. There are however people who dare to assert what I have myself vouched for elsewhere, that it is not just the pupils of these creatures but also those of human beings that dilate or shrink in relation to the Moon's light. But this has little to do with roundness.[301] However its aspect may vary, it contributes much to the change in the thing's shape; if gems are viewed from an angle, they look longer, but look square if seen from closer, since neither the considerable size of the longer sides nor the smallness of the shorter ones can be detected; hence from a distance it looks formed on a confused pattern which has only a "triens."[302]



The demonstration[303] is like this. Let AB be a side of a quadrilateral gem, BC be a fifth of it, let it be drawn to the side and divided equally at D, let DB be drawn, and let the eye be set at E, let AE and CE be drawn; then there will be an angle CED, larger than DEA; hence CD will appear greater than DA, and BC will appear nearly equal to BA, and closer; evidently the further E is from A and B, the higher up it is.[304] So since there are many things that deceive our senses, they seem marvellous to us. So that people say that the Blessed Antony[305] put it correctly: that those who use their intact senses have actually no need of the enlightenment that comes from literature. He used to say that the senses are not just those internal ones, but the mind and the memory, and then the reason. When freed from the bonds of faults and &1198 conditions, the mind knows a great deal that to other people looks marvellous.[306] So nothing ought to look marvellous, if fear and chance display many things to those who walk by night: that is, fires in heaven, falling stars, chasms, dancing

front (in Latin named the pupil, and in Greek *kore* and *glene*), from which comes the gaze by which we see." He does not use the word "iris" either.

[301] The following three sentences appear first in 1560.

[302] "quae solum trientem habet." The triens was a small Roman coin; the meaning here is unclear.

[303] Cardano uses the Greek word ἀπόδειξις here.

[304] This is obscure; in the context, there is presumably some element of illusion, with the effect that BC is really a fifth of AB but appears nearly equal to it.

[305] "beatus Antonius"; this is probably St Anthony of Padua (1195–1231) who taught theology through Italy and France, and a passage from one of his sermons reads: "We should speak, then, as the Holy Spirit gives us the gift of speech. Our humble and sincere request to the Spirit for ourselves should be that we may bring the day of Pentecost to fulfillment, insofar as he infuses us with his grace, by using our bodily senses in a perfect manner by keeping the commandments. Likewise we shall request that we may be filled with a keen sense of sorrow and with fiery tongues for confessing the faith, so our deserved reward may be to stand in the blazing splendor of the saints and to look upon the triune God." http://www.catholic-forum.com/saints/sainta06.htm, and fuller details at http://www.newadvent.org/cathen/01556a.htm, accessed 2 Mar. 2008.

[306] This sentence first appears in 1554.

flames, shadows, spectres, disorganised dins, howling, wild beasts, snakes, robbers, thieves, corpses, ghosts, devils, whisperings, groans of those in trouble, rabid dogs, and as I said, terrors without obvious cause. But these things do not show that they are themselves demons.

[655] &1198 Book XIX
On Demons

There is, then, serious uncertainty about demons; and it seems to me that people who think they exist and associate with us distinguish their arrival from divine inspiration and from association with angels in this way: since the human soul[1] naturally recoils from demons, the mind itself is confused by their presence, recoils, and is afraid of something with which it still is not acquainted. Evil thoughts commonly sneak up in evil actions, or in the treachery we plan. They also create or leave behind foul stenches and confused sounds; suspicion or despair persists after their withdrawal, as is recorded about the genius of Brutus.[2] But whether divine inspiration or some angel makes an appearance, it only presents itself to those endowed with a virtuous[3] mind, and makes its approach gradually and without any din, and cheers the soul and provides confidence and &1199
excellent hope. At that time, a calm mind is drawn into excellent thoughts, and even constrained into love of higher things. It has a regard for heavenly things, and enters a person who has good and wholesome plans. And the soul, if frightened off by its sudden arrival, at once settles down again. The Blessed Antony,[4] who was excellent in this field, explained it to us. We will retain unshaken the distinction between the deadly and the wholesome forewarnings of the soul, even if we maintain that only the latter happen through the force of nature; if

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[1] "animus."

[2] Plutarch (*Life of Marcus Brutus*, 36. 3–4; Loeb 6: 207) wrote: "Thus one night before he passed out of Asia, he was very late all alone in his tent, with a dim light burning by him, all the rest of the camp being hushed and silent; and reasoning about something with himself and very thoughtful, he fancied someone came in, and, looking up towards the door, he saw a terrible and strange appearance of an unnatural and frightful body standing by him without speaking. Brutus boldly asked it, 'What are you, of men or gods, and upon what business come to me?' The figure answered, 'I am your evil genius, Brutus; you shall see me at Philippi.' To which Brutus, not at all disturbed, replied, 'Then I shall see you.'" There is a very similar version in Plutarch's *Life of Julius Caesar*.

[3] "bonus."

[4] "beatus Antonius"; see n. in Book XVIII at 1197 (1560).

instead of angels and demons we suppose wholesome and hostile stars, the basis is the same, and the same signs will serve in each case.

So there are many people who try to show that demons exist, from the evidence of spells[5]—whether we are to rely on the experiences of Constantine,[6] for catching fish and preserving wine, in his books on *Agriculture*, or to extract arrows, or soothe toothache, or arrest haemorrhage, as we have even found in our own case.

But let us set this aside, and give an account of the miracle that we saw last year.[7] A woman of patrician descent was suffering with burning urine, and an unending inclination to void it; all the most celebrated physicians of our town had been summoned, no fewer than seven, and also others from outside, and a number of surgeons, and I too was present. But we were not reaching consensus about the cause of the disease: stone, erysipelas, ulcer, scirrhus, carcinoma, phlegmon, bladders;[8] one person and then another was taking a view, and none of the remedies did any good, though tried one by one. And when the bladders were stimulated with hot fomentations and incised, in addition to the usual sleeplessness and &1200 agony, involuntary emission of urine came on because of the incision. Then she had two convulsions, with collapse of her pulse and well-being.[9] Thus tortured by the disease and the remedies over seven months, her health was despaired of, and everyone abandoned her. There was no chance that she was simulating the disorder, for she drank so many bitter medicaments, and endured so many fomentations and fumigations down below,[10] and underwent inspections of the place by mirror at the hands of so many physicians, and put up with fasting for so long, incision of the bladders, scarring medicaments, cauterizations.[11]

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[5] Instead of the rest of this sentence, 1550 and 1554 describe a remarkable engraved ring Cardano had seen, which could prevent falling in epilepsy; and a method of treating headache.

[6] There was a traveller's manual ("*viaticum*") with medical advice by a North African doctor who died about 1004. This manual was popular in the Muslim world, and it became equally so in Europe when one of the first medical translators, Constantinus Africanus (ca. 1015–1080), produced a Latin version—which he claimed as his own work. Some 30 editions of works translated by him, including the *viaticum*, and published in 1510–1560 are held by the British Library. See L. Matheson and R.S. Moore, "Constantinus Africanus," *Oxford Dictionary of the Middle Ages* 2: 438.

[7] That is, in 1549; *De Subtilitate* was first published in 1550 (Maclean, *De libris propriis*, M81 [84]).

[8] "vesicas," plural since urinary and gall bladders both exist, though how the gall bladder could be involved is not obvious. Or the word may mean "blisters" rather than "bladders," since Celsus used the word in that sense.

[9] "virtus."

[10] "suffumigationes."

[11] "ferrum, ignes."

And so, though we were weary and not confident, my opinion was reached, which (as it appeared afterwards) was more absurd than all the rest: that the disease would get worse with whatever remedies; the pain was persistent in the place where the neck of the bladder joins the uterus, and now there was the utmost emaciation of the whole body; and the Hippocratic facies,[12] and involuntary outflow of urine, and permanent wakefulness had come on. There were now ulcers all round the place, produced in part by the heat and the sharpness of the medicaments, and in part by the relentless application of the cautery. But the burning from the urine not only continued but increased, and there was such an incessant desire to pass urine that some people thought a bladder stone was present. But the touch of a catheter disproved that view. So when the invalid's plight had grown well known,[13] there appeared Josephus Niger, a notable professor of the Greek language, which he taught officially,[14] but he was totally ignorant of medicine. People regarded him as a &1201 wizard, and a person prominently accomplished in harm-wreaking magic.[15]

This woman had a son of ten, whom Josephus instructed to say that he was seeing three very foul demons on foot in his mother's presence, in a triangular crystal which he had brought with him. Then when other words had been whispered in the boy's ear, the boy asserts that he sees another demon, a horseman, far taller than the first ones, with a trident, and he is tying up those three demons on foot one by one, and chaining them and taking them all off on his saddle. Then he gives instructions for watch to be kept on the crystal.

To cut the story short: the woman is convinced by this procedure, and falls asleep. The pain, the burning, the desire to urinate stop. Her lively colour comes back, the flesh returns, she conceives after this, she grew entirely better. I have as witnesses to this all the men and women of the family, and all the physicians who had been summoned. And everyone can see the actual state of affairs, since at the time she was moribund, and now is healthy. So the woman was cured either by a demon or by imagination and faith, since it is barely possible to find another third cause on top of these; if the boy was relaying the truth, and Josephus disguising the truth for fear of the law, she was cured by a demon; if the boy was persuaded by a word from Josephus to assert that he was seeing whatever Josephus asked

[12] "The nose sharp, the eyes sunken, the temples fallen in, the ears cold and drawn in and their lobes distorted, the skin of the face hard, stretched and dry, and the colour of the face pale and dusky" (Hippocrates, *Prognostic*, 2; Loeb 2: 9). It presages death.

[13] "Ergo prorsus conclamata aegra": syntax unclear and translation speculative.

[14] "publicè."

[15] "maleficae artes." Josephus Niger is also mentioned in Cardano's *De Varietate*, with the same tale as here.

him,[16] he set in motion a procedure for the [656]sake of his mother's health; she clearly got well through imagination and faith.

What is extraordinary is that if it was done by deceit, he declined any reward, and it is not obvious to what extent this is an unrewarded deception. But whether the attempt succeeds or not, might not significant disgrace arise? Hence the probability is that she was &1202 cured by a demon, and that actual demons exist and wander about. Plutarch does describe extraordinary things to reinforce this view, at the start of his life of Cimon, in connection with Damon;[17] also about Pausanias[18] and Cleonice, the Byzantine virgin, whom he rashly slew though he loved her.[19] Also by Pliny in the seventh book of his *Letters*, about a

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[16] "interrogaret": word classically used only of asking a question, not of making a request.

[17] Plutarch (*Cimon*, I. 2–7; Loeb 2: 405–7): "A Roman captain of a company that wintered in Chaeronea became passionately fond of this youth, who was now pretty nearly grown a man. And finding all his approaches . . . repulsed, he showed violent inclinations to assault Damon . . . Damon, being sensible of this, and looking upon himself as injured already, resolved to inflict punishment. Accordingly, he and sixteen of his companions conspired against the captain . . . they all daubed their faces at night with soot. Thus disguised and inflamed with wine, they set upon him by break of day, as he was sacrificing in the market-place; and having killed him, and several others that were with him, they fled out of the city . . . The council . . . pronounced sentence of death against Damon and his accomplices. This they did to justify the city to the Romans. But that evening . . . Damon and his confederates, breaking into the hall, killed them, and then fled again out of the town . . . Damon continuing to ravage the country all about, the citizens . . . enticed him into the city, and . . . made him Gymnasiarch; but afterwards as he was anointing himself in the vapour baths, they set upon him and killed him. For a long while after, apparitions continuing to be seen, and groans to be heard in that place (so our fathers have told us), they ordered the gates of the baths to be built up; and even to this day those who live in the neighbourhood believe that they sometimes see spectres and hear alarming sounds."

[18] A king of Sparta.

[19] Plutarch, *Cimon*, 6. 4–5; Loeb 2: 421: "They tell of Pausanias, that when he was in Byzantium [in about 480 B.C.], he solicited a young lady of a noble family in the city, whose name was Cleonice, to debauch her. Her parents . . . were forced to consent, and so abandoned their daughter to his wishes. The daughter asked the servants outside the chamber to put out all the lights; so that approaching silently and in the dark toward his bed, she stumbled upon the lamp, which she overturned. Pausanias, who was fallen asleep, awakened and startled with the noise, thought an assassin had taken that dead time of night to murder him, so that hastily snatching up his poniard that lay by him, he struck the girl, who fell with the blow, and died. After this, he never had rest, but was continually haunted by her, and saw an apparition visiting him in his sleep, and addressing him with these angry words:—go on thy way, unto the evil end, That doth on lust and violence attend."

And a different Pausanias, the author of *Description of Greece*, who flourished about 180 A.D., presents essentially the same story (3 (Laconia), 17.8–9; Loeb 2: 107–8).

ghost which used to be seen all the time in a house at Athens.[20] Also about boys whose hair was cut off without anyone doing it.[21] Again from Suetonius, in the case of the slaughtered Caligula, whose house was disturbed for many years by manifestations,[22] till it was destroyed by fire.[23] Marco Polo of Venice records that Tartary (a word that used to mean part of Scythia and part of Parthia) is so rife with the prodigies of demons that they can bring on darkness when and where they wish, and anyone overtaken by robbers through this technique could barely escape.[24] As authority for this is available a man of weight, Haitonus,[25] in his history of the Sarmatians, who wrote an account of how the battle line wavered in battle, but was restored and made victorious through a spell of the Tartar standard-bearer, who spread out the blackest darkness.

But I append the most remarkable of all the tales, which I heard not just once, but a number of times from my father, Facio Cardano, who used to claim that he had had a family demon for about thirty years. Finally, when I was looking into what he had written, I found what I had often heard set down in writing and for the record.[26] "On the first day of August, 1491, when I had completed the religious rites at the twentieth hour of the day, seven men made their customary appearance, clad in silk clothing, with a robe like a &1203 Greek one, with purple boots (as it seemed), vests with shiny and reddish chest portions,[27] so that they seemed to be from a chemise,[28] of a shape narrower than the usual, and quite conspicuous. They were not all dressed like this, but two, who were accepted as the most important of them; there was another of them who was taller and fresh-faced, and two others were his followers; another who was rather pale and smaller of body; three others. So they were seven in all." The written account left unstated whether there was anything on their heads or they were bare. Their age was around the fortieth year, but not less than the thirtieth. When asked who

[20] Pliny (the Younger) reports in his *Letters* (7. 4–11; Loeb 1: 545–47) the tale of a spectre in a house at Athens whose appearances caused great distress; finally the philosopher Athenodorus spent a night in the house, followed the spectre's guidance, and caused a buried corpse to be exhumed and given proper burial, with the desired effect.

[21] "absque authore ullo."

[22] "ostenta."

[23] Suetonius (*Gaius Caligula*, 59) reports this.

[24] Marco Polo (*The Book of Ser Marco Polo*, vol. I, 90; Book I, chap. 18) mentioned that the "Caraonas," sons of Indian mothers by Tartar fathers, could produce darkness extending over a seven days' journey, for plundering and creating a desert.

[25] Hayton (Het'um), *La Flor des Istoires d'Orient*, trans. R. Pynson (1520), ed. G. Burger (Toronto: University of Toronto Press, 1988). An English translation by R. Bedrosian is at http://rbedrosian.com/hetumint.htm

[26] "memoriae."

[27] "subuculae thoracibus splendentibus ac rubentibus"—syntax unclear.

[28] "chermesinum"; but "chemise" is derived from Low Latin "camisia," mod. Italian "camicia," a nightgown.

they were, they answered that they were, so to speak, people of the air, who were themselves born and died, but their life was much longer than ours, so that it might reach 300 years.[29] On being questioned about the immortality of our soul, they stated that nothing survived of each person's own; they were themselves much closer to the gods than to the human race, but were still separated from them by an almost infinite gap. In comparison to us, that they are either happier or more wretched, as we are in comparison to the beasts. Nothing of the hidden things is concealed from them, for instance not books, nor money; and their lowest refuse is the geniuses of the most important men, just as the most worthless of people are the trainers of superior dogs or horses. They said that since they are themselves very slim, they can bring us nothing to our advantage or detriment, apart from spectres and terrors—and then knowledge.

There were others who were of smaller body, 300 disciples, and &1204 another 200 in a public academy. Both of these were teaching professionally in public. My father asked why they did not reveal treasures to humanity, if they knew about them? They replied that for anyone to pass this on to humanity was prohibited by the private law, under extreme penalties.

They stayed with him for more than three hours; they debated meantime on his question about the explanation of the world. The taller one was denying that God had created the world from eternity; another, on the other hand, was adding that over individual moments God created the world in such a way that if he were to stop for even one moment, the world would pass away at once. He was drawing some more from the disputations of Averroes, although that book had not yet been found.[30] He used to mention the names of certain books, of which a part had been found, but a part is still undiscovered. Yet all these were works of Averroes; he used to call himself an Averroist openly. Whether this is history or fable, that was how he was. What looks like a fable needs to get enough proof, because these views do not agree sufficiently with religion, and because my father with his demons was in no respect happier or richer or more popularly celebrated than I, who have never seen any demons.

To this he would reply that he had foretold a number of things which could not be known so long beforehand without the help of demons; for instance, that the Emperor would finally prevail in Italy, which occurred barely 30 years later; that demons are liars in comparison to the word of truth, and (he said) he[31] is the

[29] Burton (*Anatomy of Melancholy*, Part I, sect. 2, memb. 1, subsect. 2; 161) relays the essentials of this tale from Cardano, but expands the "300 years" to "700 or 800."

[30] The *Quaestiones* of Averroes into Aristotle's *Analytica* (earlier books) in a Latin translation by Helia the Jew appeared in 1497. I have traced nothing by Averroes called *Disputationes* in Latin.

[31] The Devil.

father of lies.[32] That he[33] had cared little for riches or honours, for which I would be more eager; that he was born of humble fortune, and his start had &1205 stood in his way. Finally, that perhaps I possessed greater genius, and far more than others, even if demons did not present themselves to them nor to me, but they were not lacking for his aid at each opportunity. His own manifested itself to him, but others did not do so to others, either because that was appropriate, or because it was better and of purer mind. It was an excellent one, and besides, and subsequently, very religious—perhaps because it made use of intrigue,[34] which it is agreed it received from a dying Spaniard.[35] Similar is what is said about children, and pitchers, or fingernails. We have refuted this elsewhere as demonstrated falsehood. The one thing that appears remarkable is what happened to Didius Julianus the Emperor,[36] when from a mirror a child predicted enemies on their way, by whom he would be killed. And now Ioannes Leo Africanus recounts that in the town of Fessa,[37] a seer poured a drop of oil into a vessel full of water, and when it came clear, replies about the future were provided through children, who assert that they see squadrons of soldiers in the water.[38] But he does not mention that he knows more than what the ordinary people here know, nor that he has looked into the matter more carefully.

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[32] "When he [the Devil] speaketh a lie, he speaketh of his own: for he is a liar, and the father of it" (John 8: 44; in the Vulgate Latin, "cum loquitur mendacium, ex propriis loquitur, quia mendax est et pater eius").

[33] Cardano's father.

[34] "coniuratio."

[35] Grafton (*Cardano's Cosmos*, 167) points out how here Cardano has "left the reader with the clear suggestion that his father had conversed directly with spirits—though he himself seemed to deny the possibility of such communication." The rest of this paragraph first appears in 1554.

[36] Emperor in 193 A.D. For his biography see *Scriptores Historiae Augustae*, 1. 7. 10; there, the tale is told that boys were told to "look" into a mirror blindfold with the top of their head bewitched, and one of them foresaw the arrival of Severus and the overthrow of Iulianus.

[37] See n. in Book XVIII at 1158 (1560).

[38] In Book III of his *History and Description of Africa* (trans. Pory, 2: 457–58) Leo describes fortune tellers who by "powring a drop of oile into a viall or glasse of water, make the said water to bee transparent and bright, wherein . . . they see huge swarms of diuels [not the 'soldiers' of Cardano's account here] that resemble an whole armie . . . The foresaid glasse-viall they will deliuer into childrens hands scarce of eight yeeres old, of whom they will aske whether they see this or that diuell." See also notes in Book XVIII at 1158 (1560).

There are also other pieces of evidence too about demons: the reponses of oracles. For instance, the one of [657]Theophrastus about the wild olive at Megara;[39] instances are mentioned elsewhere in which Aristotle and Plutarch worked hard to produce an explanation. There also appear to be "Telchines,"[40] underground demons that cause overwhelming disaster by their digging, or choke people with some fiery spirit.

In connection with oracles, many people have wondered whether they were uttered through the priests' trickery; others have it that there is a special nature of that land, through which the "disease" &1206 is caught; the trance is a sort of disease, and the oracle only happens during a trance—yet not along with it either. So there is great uncertainty on these points.[41] Pausanias adds to it, a reliable man (as I said) in what he reports he saw himself. On this issue there is no one more trustworthy, since he had personal experience. I would like to insert his own words:[42] the cave of Trophonius,[43] "into which he descends in the following way. They take away by night the man who is going to enter, to the river Hercynus, and then he is anointed with oil and washed by two boys, sons of citizens, aged about thirteen—they are called Hermae or Mercuries. They wash him as he goes down, and do him any needed service, like slaves. Then he is not taken at once to the oracle, but is led by the priests to the water fountains that are linked together close by. There he should drink what is called the Water of Oblivion, to bring on forgetfulness of all he thought previously. After that, he drinks another water, that of Memory, so as to remember what appears on the descent. After that, having gazed upon an image (which they say is the work of Daedalus, and the priests show it to no one except those who go down to Trophonius), he does it reverence after praying to it, and proceeds to the oracle, clad in a linen tunic, and girt with bands[44] around his tunic, and also shod with a sandal belonging to the place. The oracle is above a wood at a mountain. Its base is set in a circle with

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[39] At Megara it was said that if the wild olive tree in the market-place were cut open, the city would be taken and plundered, which came true when Demetrius took it (Theophrastus, *Historia plantarum*, 5. 2. 4).

[40] Semi-divine beings living in Rhodes, skilled in metal-work and magic, dangerous and mischievous. Finally destroyed by one of the greater gods, or at least driven from Rhodes, and bearing some resemblance to the dwarves or gnomes of northern European mythology (*OCD*). Mentioned by Strabo (*Geography*, 10. 3. 7 & 19; and 14. 2. 7) and other sources.

[41] Material from here to [A] on 1220 (1560) first appears in 1554.

[42] The quotation that follows is from Pausanias, *Description of Greece*, 9 (Boeotia), 7–14; Loeb 4: 351–5.

[43] This was at Lebadea, in Boeotia in central Greece. Trophonius was the legendary builder of Apollo's temple at Delphi, along with Agamedes. On his activities see H. W. Parke and D. E. W. Wormell, *The Delphic Oracle*, 2 vols. (Oxford: Blackwell, 1956), 1: 368.

[44] Reading "vittis," not the "vitis" of 1560.

shiny white stones. The circumference of the base is like a tiny altar. Its height is perhaps a little short of two cubits.[45] Pointed &1207 brass spikes rest on the base, and there are chains that link them. Doors are constructed leading through them within the circumference.

The chasm was not created by chance or by nature, but built by technical skill and precise engineering.[46] The shape of the actual structure resembles an oven, with a width (so far as one can guess) of about four cubits, and the depth does not go beyond eight. A descent into the pavement has not been built, but when anyone comes to Trophonius, they present him with a light narrow ladder which is placed within the structure. The aperture through which he gets down to Trophonius has a width of one and a half feet,[47] and a height of three quarters of a foot. So on his way down, he lies on his back on the ground, holding honeyed cakes, and first inserts his feet into the chasm, and gets his knees in gradually by bending them. When he has inserted his knees, the rest of his body is all drawn in at once, like a great fast-flowing stream, and quickly sucks in the man with its eddy.

But those who have entered the sanctuary are not all instructed in the future in one and the same way, but some perhaps see it openly, while others hear about it. Those who go down return through the same narrows, putting their feet out first, then the rest of their body. We have not heard of anyone dying who has made his way in, except one of the henchmen of Demetrius,[48] who had gone down without any rites having been performed, and without consulting God, hoping to get away with gold and silver; it is said that his corpse was not ejected through the sacred aperture, but turned up elsewhere. So what happened to him, and what befalls &1208 those on their way in and who have entered, has been covered by me and is well worth mention. The priests receive anyone emerging from Trophonius, and put him on a throne called the throne of Memory; it is quite near the shrine. As he sits there, they question him on what he saw and heard. With this noted, they entrust him to those whose responsibility is to care for him. They remove him into that structure where he used previously to pursue his life among fortune and good genii,[49] and he is still smitten with fear, unable

[45] See n. to 26 (1560) in Book I.

[46] "compositio accuratissima."

[47] "duorum dodrantalium."

[48] From Pausanias (*Description of Greece*, 9. 39. 12) it is probable that this is Demetrius Poliorcetes (336–283 B.C.) of Macedonia, son of Antigonus I.

[49] Pausanias (*Description of Greece*, 9. 39. 5) says that the building for lodging before approaching the oracle was sacred to Fortune and to a good Spirit, and simply that he returned to the place where he had lodged previously.

to recognise himself nor those nearby. After he considers this, just as much as what he was previously considering, he bursts out laughing."[50]

I am not reporting what I have heard, but I once saw it, and myself consulted the oracle of Trophonius. I would like to attach the account of a judicious and truthful man, and one who took part in business, as an uncommon and reliable account; for there are very few people who have penetrated to such places, and most of them are stupid, and the rest think lying a substitute for fame; hence I have woven this tale in here. However great the priestly tricks you may invent, it cannot be attributed to a trick that he was snatched in as though by an eddy, and thrown out by the feet. If this was due to the nature of the place, it must surely be the case that what he was hearing was not contrived by a trick, since in a place of such violence, no one could stand to contrive an artifice. But you will say that the replies of oracles are ambiguous. It was shown in the book *De Fato*[51] that if oracles were not ambiguous, they would not be oracles. Likewise with the predictions of mathematicians, but not for the same reason, and not all of them. &1209 As I said, this has been proved elsewhere.

But what Philipp Melanchthon[52] sets out in the second book of his *Progymnasmata Physica* is extremely clear; he says that in 1530 at Nuremberg a demon had shown a priest in a crystal the location of hidden treasure, in an excavated site near the town, and he took a friend (who later told the tale) and they saw a chest with a black dog lying beside it as its guard. The priest had the courage to go in, and was at once overwhelmed by the collapse of the place. Here nothing is needed except confidence in the person who wrote to Melanchthon, since Melanchthon did not say that he had been present himself. It is agreed that he lived in Saxony, or anyway far from Nuremberg; we have no doubt of his reliability.

But there are other experiences[53] of this issue: I wish to insert from his letters two from Erasmus of Rotterdam, a learned man and almost free of superstition,

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[50] Pausanias (*Description of Greece*, 9. 39. 13) in fact just says that he recovers the power of laughing.

[51] Cardano's own work *De Fato* is mentioned by Maclean (*De libris propriis*, 53) as almost certainly destroyed after 1570, though written in 1533. Maclean reports that Alexander of Aphrodisias (see 117 [1560] of Book II) also had written a *De Fato*, which seems much more likely to be the work in question here (see Bibliography), and does discuss closely relevant issues, but I cannot identify the actual statement made here.

[52] On Melanchthon see n. at 862 (1560) in Book XII. The account is in Melanchthon's *Initia doctrinae physicae*, the orthodox name for the treatise Cardano cites as *Progymnasmata Physica*, Bk. II (*Opera omnia*, ed. Bretschneider, 13: 323) and runs: "Diabolus . . . Noribergae recens anno 1530, sacerdoti in crystallo thesauros ostenderat. Hos cum loco perfosso ante urbem quaereret sacerdos adhibito amico spectatore, cumque iam vidissent in specu arcam et atrum canem cavem cubantem ad arcam, ingressus sacerdos in specum opprimitur, ac interficitur ruente cacumine, et specum rursus complente."

[53] Maclean ("Interpretation of Natural Signs," 237) draws attention to how Cardano includes here some aspects of one's reading as part of one's experiences. It seems that

so that even in his *Spectrum* he ridiculed such things freely.[54] The Germans call the village about which the tale was told you Schiltach. It is eight long German miles from Freiburg, and I dare not [658]state whether all the common boasts about it are true. What is extremely true is that it all suddenly burst into flames, and a woman confessed and suffered punishment. The conflagration happened on the tenth of April, which was the Thursday before Easter, in the year 1533 A.D.[55] Some citizens of this village recounted in front of the magistracy of this town this occurrence as a fact, in the way that Henricus Glareanus[56] reported it to me, so far as I can remember. &1210 The demon gave a signal by a whistle from some part of the house. Suspecting there was a thief, the innkeeper came up, but found no one. But the same signal was given again from a higher attic. And the innkeeper made his way up there, in pursuit of the thief. When no one appeared there either, the whistle was heard from the crest of a smoke-chamber. At once it crossed the innkeeper's mind that there was something demoniacal; he told his people to be on the alert. Two priests were summoned, exorcism was applied. It replied that it was a demon. Asked what it was doing there, it says it wishes to burn down the village. While the priests were threatening it, it replied that it cared nothing for their threats, because one of them consorted with prostitutes, and both were thieves. Sometime later, there was a woman with whom it had had an affair for fourteen years, though in the meantime she confessed every year and took the Eucharist; it raised her into the air, and set her on the crest of the smoke-chamber; it handed over a jar, and told her to turn it upside down; she did so, and within an hour the whole village was burnt down. I have not heard for sure whether the demon destroyed the village and abandoned the woman through outrage because the innkeeper's son had been brought in as its rival; however, this is not different. The rumour of this nearby occurrence is so consistent that it cannot appear fictitious. There are other occurrences of this

for him, what is *read* acquires authority comparable to that of other personal experience—not the view of Fallopius, Vesalius, Harvey, or Malpighi—nor that of later experimental science.

[54] In the *Exorcismus sive Spectrum*, a *Colloquium familiare* of Erasmus, he relates how one "Polus" deliberately provoked the impression in a party of people near Richmond [now a suburb of London] that they could see a terrible dragon in the sky with fiery horns and a tail bent in a circle. Within three days an embroidered rumour went all round Britain; one "Faunus" became a particular victim of the ruse, was made to hear fake voices and see fake spectres, and set about performing a ceremonial exorcism: *Exorcismus sive spectrum*, ed. L.-E. Halkin et al., in *Opera omnia* 1. 3: 417–23; trans. C. R. Thompson (Chicago: University of Chicago Press, 1965), 230–37.

[55] This is correct; the Julian Calendar was then in force and for a further couple of centuries at least. See http://www.medievalgenealogy.org.uk/cal/key16.htm, last accessed 3 Mar. 2008.

[56] Henricus Glareanus (1488–1563) was a Swiss humanist, poet, and student of music who was made poet laureate at the age of 24 by the Habsburg Emperor Maximilian.

sort, but I prefer not to weary your ears with the tales of common people. In this case, the basis is not in doubt. Someone could say that it was a woman's trick, and an act of despair. But everything seems to fit so nicely that this can hardly be believed, since the demon could not incinerate the town, but could provide the jar and persuade the woman.

Listen to &1211 another story of the same kind. Last year at Magdunum[57] (a little village not so far from Orléans)[58] a criminal about to depart[59] commissioned his wife to hand over any magic books at his place and the remaining equipment of his sacred rite to a citizen of Orléans, who was plainly soon to die, because he regarded him as conscious of a crime and a sharer in it. He moved all this to Orleans.

Now the priest of his house, over three years, is completing an abominable rite, the more execrable for some sort of idol-worship, with his wife's collusion and also the aid of his virgin daughter.[60] In what rites and ritual this sacrilege consisted I will mention briefly, as I have heard it from very reliable people. The revered body of our Saviour he had hidden in a small box of willow wood hidden under his bedclothes. O divine patience!—as I tell the tale, a chill horror shakes my limbs. He had bought this three years earlier from some famished and impious sacrificial priest (there is too large a supply of this sort), and indeed I think bought it for less than long ago the Jews bought Christ, so that this appalling criminal priest not only repeated for us what Judas did,[61] but even outdid him; and rumour has it that he paid the penalty of his impiety by a sudden death. So every time this villain started not on divine but on diabolical business, he used to bring out the heavenly mystery with profane hands, and it was being displayed torn from the bedclothes and bared. The daughter, still a virgin, used to hold a drawn sword in her upraised hand, because that role could only properly be filled

[57] Méhun-sur-Yèvre, which is about 10 km NW of Bourges in the Cher Département of France.

[58] Aurelia: Orléans in France, and Méhun-sur-Yèvre is about 100 km south of it.

[59] "decessuro"—might mean "about to die."

[60] The reverence paid by the Catholic Church to the ceremony of the Mass, and especially to the Host (bread altered into the body of Christ by transubstantiation), kindled irreverence well before Cardano's time; a case where the Host was alleged to have been deliberately thrown into a privy is reported in a confession of 1233 (G. Zacharias, *The Satanic Cult*, trans. C. Trollope [London: Allen & Unwin, 1980], 52). Numerous such episodes included one at the French court in 1574, when Catherine de Medici organised such a mass to aid her son Charles IX of France, with a black 3-cornered Host and a white one (H.T.F. Rhodes, *The Satanic Mass* [London: Rider, 1954], 62). The *Malleus Maleficarum* (Frankfurt, 1588; ed. and transl. P.G. Maxwell-Stuart [Manchester: Manchester University Press, 2007], II. 5 [146]) recounted many such episodes, including one where the Host was thrown "into a pot in which there was a toad, and hidden underground."

[61] Judas was the disciple of Christ who betrayed him for thirty pieces of silver paid by the Jewish authorities (Matthew 26: 15 onward).

by a virgin, directing the point &1212 at that sacred body, I mean like someone threatening it. Then some head would be produced, made of some material or other, engraved with a triple face, representing that triple unity and single-formed triad.[62] It was surrounded with a nine times reduced circuit. Among these were a thousand "T" figures, inscribed with the unheard names of the angels; later, the same number of separate circuits of cacodemons with revolting names.

When these had been assembled like this, there came the wicked priests, with opened books and those prayers of execration. With Hecate[63] calling first upon the venerable Trinity, and very numerous angels each in its chorus; then he calls on the six hundred names of cacodemons, and does not stop till that particular demon is at hand, and responds on the spot to his call. He was the manufacturer of great treasures, or at any rate the guide to them. This criminal had promised[64] his priest mountains in Persia, and also a quantity of largesse, but so far below the priest's hopes that the fellow started to repent of his effort, indeed three years of it. And so he calls on his paymaster[65] with the usual entreaties, and grumbles that he has been led on and seduced simply by hope, and made nothing worth while. The other excuses himself, saying it is not his fault, but there is something missing in the rites which needs a man of letters; if he can get one, he will point to treasures beyond anyone's wishes.

And on being asked at the same time who would be best to enlist in this cause, he suggests the Prior of the monastery of monks of the order of Preachers [Dominicans], which is behind the walls of Orléans;[66] let him approach, and cautiously sound out the man. This man is a trained Bachelor of Theology &1213 (as they call them), of some repute among common people, and not at all the worst of debaters,[67] as theologians are at present. But as I thought later, highly greedy for celebrity (and they generally are like that). But I am not even in pursuit of a guess at what that evil genius was after, to be coaxing his priest (already thinking of breaking loose) straight to destruction—or that he genuinely promised himself that a theologian's mind could be corrupted by the size of the suggested reward. In this confidence, I think that (as Vergil wrote, under divine inspiration) the accursed greed for gold constrains mortal hearts to anything.[68]

Then, as people say, there are those who associate quite familiarly with this sort of people, and under those hoods and the reputation of destitution, there

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[62] The Holy Trinity: Father, Son (Christ), and Holy Spirit, three and yet one.

[63] An earth goddess linked to Hell, worshipped at cross-roads, and represented with three faces or bodies.

[64] Reading "promiserat" for the "pomiserat" of 1560.

[65] "promissor."

[66] See n. 58 above.

[67] "concionator."

[68] Vergil, *Aeneid*, 3. 57.

sometimes lurk highly scandalous minds, blazing with unbearable arrogance and extreme lust for money. But we leave this undecided. A man who has been convinced meets a fellow, and so as to test his mind little by little, he pretends he has some manuscripts at home, of no use to him as an unlettered person, but extremely useful to an educated one. He asks him if he wants to [659]buy some. The theologian asks for them to be produced, obviously for inspection. He brings out an Old Testament, which is commonly called the Bible, translated into French. When the theologian thinks little of this manuscript, and asks whether he has any others, he produces another concealed in his bosom, reluctantly and as if disparaging it. When it is unrolled and he has noticed that it is the work of a &1214 master of the disreputable arts, I do not even know whether he was taken by its novelty (as does happen) and looked at it with more interest, or whether he was entirely unravelling the trick which he felt was being played on him.

So on being asked what he would like, he replied that the book seemed to him harmful.[69] Then he held out for confidentiality, by earnest entreaty, and says that he has some books of the same sort at home, but they need the attention of a learned person; otherwise the vast treasures in these books could get burnt.

The fairly upright[70] theologian asks for him to bring these too to him for inspection; he says this business is close to his heart and he will not go to sleep over such a divine bargaining, and he has a sure expectation that it will turn out all right. So after exchanging handshakes, the wretched man brings the rest of the books, the theologian continues to fish out information, till the fellow is now at ease about his intention and makes himself clear about it all—and at last, about Christ's body. On that issue he seems extremely glad, and presses eagerly for such important items[71] to be shown to him, saying that he is pondering the ripening deal with all his heart. The man takes him to his home, and requests his wife to bring out that secret thing and the other equipment for harm-wreaking magic. They are brought out and inspected.

The monk pretends to do something quite different (as he says himself), but reports the matter directly to the person called the Official, a man of really total honesty, and renowned for his complete command of both types of law, and fond of me to quite an extent.[72] In such an extraordinary business he felt there should be no delay, and threw the man into prison along with his wife and daugher, the theologian betraying him through the royal ministers. An immediate rush to church; &1215 this venerable secret was produced with appropriate respect; and what was left of the day and the whole night were celebrated by the clergy and the monks (who were practising vigils),[73] with solemn chants and prayers.

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[69] "maleficum."

[70] "arrectior," rare in classical times; sense uncertain here.

[71] "res."

[72] "nostri maiorem in modum amantem."

[73] "excubiae."

The following day, a solemn supplication was proclaimed; the roads were arrayed with tapestries on both sides on the outward route and the return route to the church.[74] Every church in the town was resounding from the sacred bells. All the clergy proceeded, each with their own relics, and the whole city poured forth to the sight; and with suitable pomp the sacrament[75] was picked up from the criminal house and conveyed into a church sacred to the cross that brings salvation. There, before a gathering more crowded than people said had been previously seen, the theologian set out the whole business, incurring some suspicion of boasting; he averred repeatedly that Christ's body had been placed there in the open air, as it was removed from the house of the criminal. What he had done he was going to do again next day, and successively, and while they had admitted each thing to him in privacy,[76] he would report it daily to the people. And I think he felt that a very sure means of obtaining immortality had been offered to him, but the Official, no fool, enforced silence on the theologian who was now fluttering in a windy chariot of vanity.

They[77] are examined and given a careful hearing by theologians appointed at Paris for this purpose, and two jurisconsults were in attendance as well. The Official told us that some sensational things had been revealed by the man during questioning, but could not be taken as certain yet—what he was saying was still not very consistent[78]—that by night a woman was tormented in wretched ways by a cacodaemon, pricked, cut, dragged off, and almost killed. But her daughter, confident in herself, was not disturbed by &1216 any fear of punishment, because each day when daylight came someone was available, she said, who soothed her and removed all her distress, and told her to keep calm.

The widow of the magician whom I mentioned above is held[79] at Magdunum.[80] This is what he said. It might in fact be doubted whether this unfortunate magician could ever call off a demon— and that someone suspecting there was something lacking after discussion with his wife would risk hanging.[81] For if the demon was addressing him, it could tell him what was missing, and not send him off to perdition, since it was already his. And if he had stopped, he was not going to get better, since he was not going to reach God or to search for Him, but going to desert the demon in resentment. But the demon is a traitor, and fails his followers. Let this be granted; but there is no one so bad as to be his own adversary. This was to drive people away from pursuit of the evil arts, and from keeping

[74] "quaque ibatur, quaque ad templum redibatur."

[75] I.e. bread, blessed and then regarded as "transubstantiated" into Christ's body.

[76] "in cuniculis."

[77] It is not clear who "they" are.

[78] "quod ipsum sibi parum adhuc constare diceret."—syntax unclear.

[79] "tenetur."

[80] See n. 57 above.

[81] "in laqueos incidisse."

watch on themselves, which he is supposed especially to require. But though this is in doubt, it still does provide great suspicion in case there was something, because of the consolation of the daughter. But much could lie undetected. Thus it appears that God wished us to be ambivalent in these matters.

Pausanias also reports that in Attica, during each night on the field of Marathon, where Miltiades had slaughtered a hundred thousand Persians four hundred years previously, and where King Icarus too had been killed previously,[82] the neighing of horses is heard, and the encounters of fighters;[83] this was not happening to everyone who took the trouble to visit this scene[84]—they &1217 were only audible by chance to those who met there. It appears that the Supreme Craftsman wished to leave us so completely in doubt that the rewards of faith were owed to the good, but penalties to the bad and faithless. But if the souls of Persians there were creating a disturbance at all, the souls of the horses that were neighing should have survived too. So what is more likely will be that a little after that vital combat, a tale was summoned up through some natural cause, and has been current to the present day, so that people could attribute any kind of noise to the confused neighing of horses and the encounter of fighters—in any night noise that comes from the earth, usually there is a lower-pitched part and a higher-pitched part. The lower-pitched is traced to the encounters and the groaning of human beings, and the higher-pitched part to the horses neighing. Thus, leaving the ancient instances, we come down to some of our own time.

In his Indian history, Nicolaus of Venice[85] reports that when the winds had ceased, an Indian sea captain called on the god Mutthian, as he used to name him, and that finally the god descended into some Arab, and possessed by the god, the Arab shouted out and ran along the ship to reach a plank which had been attached to the mast [660]for this reason. The account runs that he also swallowed charcoal that was there, and went to get a cock's blood, which he sucked out after throttling the cock; then he asked what they wanted. On the captain's replying, "Winds, and from the West,"[86] he promised to give them within three days. He also warned them to be ready for the opportunity. When the spell

[82] Pausanias (9. 11. 5; Loeb 4: 219–21) states that Icarus, the son of Daedalus, was drowned through the overturning of his ship, and was buried on a small island off Samos. The well-known alternative tale that Icarus fell from heaven through a too rash approach to the Sun, while accompanying his father on a bird-like flight, is in Ovid (*Metamorphoses*, 8. 183–235). Neither tale mentions Marathon.

[83] Pausanias (1. 32. 4; Loeb 1: 175) does give this story.

[84] "spectaculum."

[85] Niccolo di Conti (ca. 1395–1469), Venetian merchant and traveller, visited Baghdad, India, Sumatra, Java, Indochina, and Burma (see http://www.win.tue.nl/~engels/discovery/conti.html, last accessed 3 Mar. 2008).

[86] "qua ex parte ex ponente"; "ponente" is the West wind, a post-classical word.

had expired, the Arab recalled nothing of what he had predicted or undergone. &1218 Yet when the time came round, everything fell out as he had said.

Thus it appears that demons have some power or foreknowledge, but much has been effaced through scorn. The scorn has come about because most people who have put trust in these skills have not only come to a bad end, but have achieved nothing of note in their skill. This has happened not so much because the skill is shallow, as because of the rashness of its practitioners, who have promised themselves much through this expedient alone. But those who excel in arms or learning or some skill seem to have gained significantly from these practices; for instance, Pietro d'Abano, called the Conciliator,[87] is said to be one who obviously gained eternal glory with the help of necromancy, as he himself left on record. He was a man otherwise distinguished, provided he had been free of this failing.

This skill[88] used to thrive in Spain in the past, and was taught in public at the Academy of Salamanca, but is now abolished by public legislation. So some examples[89] of this skill still exist there. What was told me by Don Constantinus Fontanus, a Spanish theologian, and with confirmation from Prince Philip of Spain, was that while lodging in the Spanish city of Pinthia, or Valleoleta (its common name is Valladolid), in the house of a printer, he used to hear things badly because of the nocturnal noises, and on the first night felt an incubus; but as he had eaten black olives at supper, he thought this natural, since an incubus would be reckoned among diseases. The next night, he sees and hears cats squalling on the bed, and though this seemed oppressive, still it was possible, and so he thought this too was natural. On the third night, before he had gone to sleep, and &1219 was discussing these events, he heard a trumpet blast, as if in his ear. Taking this for a sort of whistle, he was seeing children who were there, laughing; then this voice began to move round the bedchamber, and on completing the circuit hid under the bed, clamouring for some time, though nothing could be seen.

But there is nowhere where traces of demons or of the dead can be seen or heard so much as around the dying, or after huge disasters, or in time of pestilence. These things happen in two ways when people are dying: the first is, they happen to the people themselves—anyone who sees something before dying is terrified, and after the sight, does not survive. And though it could be natural,

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[87] This is Petrus Aponensis, Professor of Medicine and Natural Philosophy at Padua, author of the *Conciliator* (Venice, 1476), an attempt to reconcile Arab medicine and Greek speculative natural philosophy. He is mentioned earlier in Book III at 246 (1560) and in Book VII at 547 (1560).

[88] I.e. necromancy.

[89] "experimenta"; for discussion of the meaning of "experimentum" and "experientia" see P. Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1994), 202–4.

it is still remarkable. I saw a very distinguished man who had got to the stage where he could not move, yet nearly threw himself out of bed, and the attendants fled, as this happened at dead of night. These things certainly happen to other people: in fact, for Princes thunderbolts, and comets, and a star in the sky are forewarnings of death, and disorderly noises are the same for ordinary people—I have often seen and heard the like, and learnt of them from others. Indeed, in the cases I have come across, I am not being deceived. Again, where many human corpses lie ill buried, there are certainly some terrible sights, but a natural explanation can be presented for them. Furthermore, in my books *De rerum varietate*[90] I have spoken about these events, and the strange voices of plague, and the likenesses of chariots that are seen and are, so to speak, suddenly overturned, with banging and crashing. For the moment it is enough to warn; experience does the convincing, but is no proof.[91] And this is the type of debate, so that &1220 for the supporters there will invariably be flight, and conflict with the opposition, while for the deniers there is experience[92]—so that these events would not seem to be turning up enough to reinforce the view of enthusiasts about demons; [A] in connection with Telchines,[93] we can offer as explanation the nature of stones, either too friable, or through corrupt spirit overflowing with sulphur, and burnt up with pitch. What surprises me more is that the air and ether are of such a size, and the region concerned is so charming, and we can see that the earth possesses its living things, metals, stones, plants, and the water its fish, and this air below that animals breathe—and so it hardly seems likely that there should be such a space[94] up there utterly devoid of life. What we should rather believe is that there are animals there as much excelling these lower ones as the region there is clearer and purer than this lower one; indeed, as I said, since we see that nature has adhered to this in the case of the other elements (and not just in their case, but also in heaven), we should believe that this whole environment[95] of the upper air is full of these animals that we call, as it were, wise demons.

I would prefer not to pursue these issues to the point of striking a balance, like Porphyry, Psellus,[96] Plotinus, Proclus, and Iamblichus, who have written at

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[90] *On the Variety of Things.* See n. at 998 (1560) in Book XVI.

[91] "nunc sat monuisse fuerit, experimenta persuadere, non demonstrare."

[92] "ut affirmantibus nunquam defutura sit fuga atque certamen contradicentium, negantibus experimenta": obscure.

[93] See n. 40 above.

[94] "moles."

[95] "machina"; the translation is inadequate and does not convey the air of a complex contraption.

[96] See D. Hayton, "Michael Psellos' *De Daemonibus* in the Renaissance," in *Reading Michael Psellos*, ed. C. Barber and D. Jenkins (Leiden: Brill, 2008), 193–215, esp. 206–8 on Cardano.

length on what they have not seen, as if offering an account of how things are.[97] I am a philosopher, adhering so far as possible to Peripatetic views; they do not admit demons, and the view that accepts them in such a huge space is improbable; they would be like the birds here, and much more crowded—yet hardly a trace appears once in a whole province and over several years. &1221 Princes too, whose good fortune suggests that they are the wisest of mortals, scorn these views and their like. What does surprise many people is that if they recognise primary lives or minds, they will be at the same time mortal and immortal, which cannot be the case. If not, what stops them from destroying the human race, as they are invisible and under no one's control?[98] It is well to know just one thing: that no honest person can claim to use demonic aid, even if there are demons, in contempt of God the best benefactor and source of all we receive, and on our own decision;[99] this is surely the action of an utterly ungrateful person, and we can see the people who interest themselves in such things, or those who are driven mad by their deceptive persuasion; religious practice agrees that they are very evil. If there is an alternative, it is that they are highly ambitious, on the evidence of their sacrifices and their nature and power. And if these things go on with God's consent, His servants obey their King. So it is generally deceptive and dangerous to rely on demonic help, and is always the behaviour of a wicked or stupid person. All is in fact of God.[100] Any spells concern the [661]soul or the body. It is to be supposed that they owe their power to mutual agreement—soul is related to soul.

Many people recoil from the remainder[101] as being impious, but I would prefer them to be genuine; there is no risk of idolatry at this stage, and we are more at risk of being Epicureans.[102] Hence if it were a matter of words alone, and particularly of those that contain Christ's name, for fish to be fetched,[103] or wine

[97] "nata res."

[98] Material from here to the opening of the Book's final paragraph first appears in 1554, apart from a portion marked as first appearing in 1560.

[99] "nostri numine."

[100] "Dei enim omnia sunt." The following sentence and the subsequent paragraph first appear in 1560, replacing a short sentence in 1554 on Peripatetics.

[101] "reliquas"—souls, presumably.

[102] The Greek philosopher Epicurus (341–279 B.C.) founded the system known as Epicureanism; among its tenets was that the maximum of pleasure was simply the absence of pain. For a summary of information see David Konstan, "Epicurus," *The Stanford Encyclopedia of Philosophy (Fall 2005 Edition)*, Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/fall2005/entries/epicurus/>. (last accessed 3 Mar. 2008).

[103] The reference here is to the miracle in which Christ directed His disciples where to let down their nets, when they had fished in vain, and a huge catch ensued (Luke 5: 6; John 21: 6).

be kept in jars,[104] or for there to be some demons, in what better way could we &1222 recall the human race to its duty?[105] In addition, enough has been said on demons and the soul's immortality in our books on Theonoston.[106]

There is doubt about whether the dead are happier than the living. The wise answer is: neither. The dead are at eternal rest in the shadow of death, and are forever free from all pain and distress, and are in pleasant ease and eternal peace.[107] Accordingly it is well written, "Blessed are the dead who die in the Lord."[108] Thus this is the final bliss of our mind. So those who are dead cannot be unhappy; those who are alive can be happy. The state of those who are dying is worse: all of them are alone, even if they are kings and fall along with many people. Everyone dies and is seen to die on his own. The loneliness, linked with bitter grief, is very distressing, and unbearable; it is a comfort to the wretched to have others share their punishment. But someone who dies, even if with a thousand others, can have no companion. There is then a huge emptiness, and miserable loneliness. Thus the greatest joy of the living is in company. People are said to be alive who live in accord with virtue, and are alive all the time. An unprincipled person lives no real kind of life; gods live both kinds; a principled person one or other kind;[109] hence such a person, if he is anything, can alone be happy, and of all mortals be closest and most like to the gods. Much more blessed than a principled person is a principled ruler,[110] for he can be compared to God.

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[104] The reference here is to a miracle worked by Christ at a wedding in Cana in Galilee, in which water was changed into wine (John 2: 7–10).

[105] "pietatem."

[106] Cardano uses the Greek θεονοστοῦ here. The work is described in Maclean, *De libris propriis*, M108 (95–97); written (or at least begun) in 1555, it reached print only in 1617, and passed under various titles.

[107] The next three sentences first appear in 1554.

[108] Revelation 14: 13.

[109] "altero"; the sense is not clear.

[110] "Princeps probus."

[661] &1223 Book XX
On Primary Substances or Lives[1]

So the life of the gods[2] is happy, unworried, eternal; that of human beings is a short spell, unhappy, and full of suspicions and fear, so that it is barred from many excellent activities.[3] Time crushes what it stimulates, and the tighter the crushing, the more grinding occurs.[4] Hence the faster the blows, the more damage they do. Nothing looks gloomier to mortals than shortage of time: it is pressing, it hinders, it frightens, it pushes one over the edge, and makes achievements incomplete. In contrast, the gods themselves have nothing to distress them, but traverse everything in an unbroken felicity. And the more long-lasting the intellect is, the more rarefied it is; the more rarefied its substance, the nearer it is to the primary cause. Even if the whole intellect enjoys perpetual peace, unworried happiness, total blessedness, immeasurable eternal light, and such a clearness that no one can picture it, even from a thousandth part of it, nor bear it for a moment, even if able to appreciate it. The Sun gives light for the intellect, and is, so to speak, a soul for it; but if the intellect could withdraw from it, the Sun would shine no differently from the earth.[5] There is however a huge difference between lives and us.[6] And between these lives themselves an even larger difference; with us, what is greatest cannot be appreciated; but what cannot be appreciated goes off into the infinite. Indeed, since our eye sheds so little[7] illumination

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[1] In 1550 and 1554 the title is instead: "De Angelis seu intelligentiis," which seems more apt for the material of this Book than what has replaced it.

[2] "divorum."

[3] "opera."

[4] "Tempus verò quae agitat comminuit, et quantò arctius, eò magis atterit."

[5] 1550 and 1554 omit the next two sentences

[6] "Maximum tamen est inter vitas nosque discrimen."—obscure, might mean "a huge distance between their lives and ours."

[7] Galen's view was that the cerebral pneuma (i.e. spiritus) emerged from the eye and then, after contact with the lit object, returned on the same path through the eye to the brain. See R. E. Siegel, "Principles and Contradictions of Galen's Doctrine of Vision," *Sudhoffs Archiv* 54 (1970): 261–76; and for a full detailed account of this view, O.-J.

brightly on the &1224 light of our soul, how are we to regard the brilliance of those intelligences with whose brightness the Moon shines, then the other stars, and—much more—the Sun?[8]

There is uncertainty over how the intelligences can take pleasure; all pleasure, as we saw previously, comes after grief or pain. Otherwise, they cannot change while experiencing pleasure; but if they take pleasure after grief, it appears appropriate to experience grief. But if they do not change during delight, there will be no pleasure; what makes no change adds nothing, and is as if it did not exist. And if it is always increasing, would it become infinite, and incapable of increase? But infinity is matched to God alone. However, if pleasure increases and diminishes, it will happen along with grief. Distress or grief do not come just with the arrival of harm, but also with reduction of the earlier happiness, as with people who have fallen out of favour with their prince or a friend. But even if they are not experiencing pleasure, they cannot be happy, and this will be little different from not existing; the people who denied that those above were happy were atheists just as much as those who denied that those above exist.

Hence there have to be two possibilities: either that our delight which is associated with movement is only a likeness of delight, or that delight in these cases is indeed quite without movement, but stems from things that are constantly changing. Maybe our delight[9] is always associated with movement, because we too are always associated with it. But in the case of those without movement, they lack delight, since they are themselves devoid of all movement. Of this situation we have some faint representation here in love, in which without any feeling of change we do not have the pleasure of desire either. But &1225 when things change, yet we do not, we do notice that pleasure occurs, since when we gaze at jewels one after another, our senses and mind are imbued with the new appearance, yet the same charm, and with no break or decrease in the delight. What these people [662]take delight in is special for them, not what is under discussion here.[10]

But we will be in a position to say that childish interests are for children, minor ones for ordinary people, public ones for magistrates, territorial ones for kings; so

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Grüsser, "On the History of the Ideas of Efference Copy and Reafference," in *Essays in the History of the Physiological Sciences*, ed. C. Debru (Amsterdam: Rodopi, 1993), 35–56.

[8] On the theme of "planetary intelligences" mentioned here and prevalent in the 16th century, see S. Meier-Oeser, "Angels in the Renaissance and the Early Modern Period," in *Angels in Medieval Philosophical Enquiry*, ed. I. Iribarren and M. Lenz (Aldershot: Ashgate, 2008), 187–200.

Material to [A] on 1226 (1560) first appears in 1554; but 1550 includes a sentence referring to Michael the Archangel, absent in later editions.

[9] Reading "voluptas" with 1554 instead of the "voluptis" of 1560, and similarly "leuem" for "euem" and "mutationis" for "muntionis" just below.

[10] "Ea autem quibus delectantur hi, eis sunt propria, non quae hic agantur."

it is with gods.[11] For that is the Latin word, more (because of the homonymy and with some suspicion of a lack of devoted worship) than genii, divi, dia-ve, minds, intellects, intelligences, or angels.[12] Aristotle calls them primary substances, principles, and souls. But on a true and Latin interpretation, though an uncommon one, we can call them intelligences; as light is nothing but brightness, and illumination nothing but clearness, so God's intelligence (as He is especially in existence and continues so, as a substance does) is a substance; if Vision were a substance, Vision and what it sees would be the same thing. We will be right to describe as eternal and immortal the lives that really do their living on their own, unlike us, who are ever between death and life, between shadow and body, between illumination and darkness, and in precarious light. Their number is not small or medium, as it seems to us, but they are innumerable. All that is like this (and there is much) has a share of divinity, and there seem no bounds to their distinction or clarity or brightness and other good points (and their different kinds are beyond our ken). Of those that come into being here, there is no knowledge nor ignorance; they are a part &1226 of those in which they themselves take delight, since they exist in some better manner before they came into being.

But the question is: into everything, and in everything, and about everything? This belongs to another treatise. [A] Dionysius the Areopagite[13] divided them into nine Hierarchies: Angels, Archangels, Thrones, Dominations, Virtues, Principalities, Powers, Cherubim, and Seraphim. The Church celebrates these names in the rituals of the Mass. And each of them differs more from another than the human intellect differs from the last of them, since none of them lacks anything in relation to perfection, as they are arranged in various kinds. Also, the greatest of them can comprehend the brightness of God much less than our

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[11] "diis": or "divinities." The following four sentences are expanded and modified in 1560 from the version in 1554.

[12] Syntax and meaning continue obscure. 1560 reads here: "Sed ut pueris puerilia, plebeis parva, magistratibus publica, regibus quae ad provincias spectant, ita diis (sic enim Latinè magis quanquam ob homonymiam, non absque suspicione cultus parum pii) quàm Geniis, Diuis, Dia´ue [correctly transcribed], Mentibus, Intellectibus, Intelligentiis aut Angelis, dicere licebit."

[13] Pseudo-Dionysius the Areopagite (fl. c. 500), probably a Syrian monk who, known only by his pseudonym, wrote a series of Greek treatises and letters for the purpose of uniting Neoplatonic philosophy with Christian theology and mystical experience. These writings established a definite Neoplatonic trend in a large segment of medieval Christian doctrine and spirituality—especially in the Western Latin Church—that has determined features of its religious and devotional character even up to the present time. Historical research has been unable to identify the author, who, having assumed the name of the New Testament convert of St. Paul (Acts 17:34), could have been one of several Christian writers familiar with the Neoplatonic system of the 5th-century Athenian Proclus. See P. Rorem, *Pseudo-Dionysius* (New York: Oxford University Press, 1993) and R. Arthur, *Pseudo-Dionysius as Polemicist* (Aldershot: Ashgate, 2008).

intellect can;[14] divinity is itself in fact separated by an infinite interval (even from the first intellect itself). The only significant distinction is that our intellect is only an inseparable representation of true intellects, yet not a true intellect. There is indeed a greater difference between a very vigorous and a very lazy horse than there is between the very lazy one and a picture of one—because the very vigorous one outdoes the very lazy one far more than twofold, yet each of them is a real horse, but a picture of one is no horse at all. Thus a picture of a horse can be compared to our intellect, but a very slothful real horse to the ultimate God; and a very vigorous one to the one next in comparative rank to him—you will clearly understand that our intellect is only a kind of shadow of a true intellect.

Though our intellect does receive from the representation of things &1227 themselves some awareness,[15] it stays full of obscurity, error, and doubt. And it does not stick to its task always, nor indeed for any long time. But these supreme intellects, clear, sure, pure, permanent, live in diligent and blessed activity.

Someone will wonder in what way one of them can be more perfect than another. The answer has to be, "Just like someone who knows that a set of six is complete, without proof." This is a question for our intellect: it has dim knowledge, and hesitates, and possesses only a shadow of things. And so the senses of beasts notice only the outer coating, while human senses notice the core; in just the same way, our intellects contrast with true intellects.[16] Likewise, someone may stand outside a handsome palace and inspect it—yet learn nothing of its contents or what is going on there, big and very beautiful though that is. Thus our mind gazes upon and marvels at the mere outside of this famed divine work of art, yet fails to reach the core of things.

Again, imagine someone following from explanation[17] that the number six[18] is perfect, and as everything is available for precise learning, the word "perfect" is appropriate.[19] Yet it is still more perfect after reaching the point from explanation that multiplied by itself, it makes itself more than tens.[20] And in addition to this, there is one more notable than the second, by dividing the cube numbers

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[14] What our intellect can comprehend here is probably that intelligence; but the Latin is ambiguous and "the brightness" might be what is comprehended by our intellect.

[15] "notitiam."

[16] The next two sentences appear first in 1554.

[17] "demonstratio."

[18] "senarius."

[19] A "perfect" number is one for which the sum of its divisors (apart from itself) equals the number. Thus 6 is perfect, having factors 1, 2, and 3. The next perfect number is 28. Further information can be found at http://www-history.mcs.st-and.ac.uk/history/HistTopics/Perfect_numbers.html, last accessed on 29 Mar. 2010.

[20] "denarios."

by itself and leaving their sides.[21] And better still is knowing by explanation that when the sets of six are arranged starting from unity and linked in sequence, &c1228 the numbers that arise, when again linked in the same order, always make cube numbers:[22]

1	1	1	.	1
6	7	8	.	2
12	19	27	.	3
18	37	64	.	4
24	61	125	.	5
30	91	216	.	6

So it is clear enough that our intellect is weak; however, we have not explained yet why. But God was not in a position[23] to make a better one, not because He could not, but because He thought it better that it should be like that.

So to get acquainted with the nature of these intellects, we will need to know the powers of the bodies that are controlled by them: the Moon governs the elements and the bodies of animate beings. Over it the Angels (that is, the messengers)[24] preside. Their chief is Gabriel, that is, God's strength.[25] For it is by the Moon's illumination that everything is conveyed to us from heaven, and it is in vigorous life. Mercury is in charge of the intellect and all the senses. The Virtues are in charge of Mercury; Raphaël[26] is in charge of the Virtues, that is, he is the medicine of God. For the medicine of mortals is the senses combined with intellect, by which the virtues are assembled in us. Venus is the mother of delight and pleasure, and unites us for the propagation of offspring. The Dominations are set over her; they actually have the power of protecting the species of individuals. Protection is achieved by generation, generation by sexual intercourse, sexual

[21] The first four perfect numbers are 6, 28, 496, and 8128, but the meaning here is not clear.

[22] This can be seen in the third column of Cardano's table below. I am indebted to Professor Alex Craik, of the University of St Andrews, for guidance here and for pointing out that the relations between the figures of the table can apply only for the number 6 and not for any other number, since they depend upon the algebraic identity (note the 6 on the right-hand side) $(n+1)^3 - n^3 = 1 + 6(1 + 2 + 3 + \dots + n)$. The 1550 and 1554 editions do not supply the Table here.

[23] "nequivit."

[24] The word "angels" in Greek means "messengers."

[25] The word "Gabriel" in Hebrew means "God's strength."

[26] Raphaël appears as the Archangel in charge of healing in, for instance, the Book of Tobit in the Apocrypha (3: 17): "and Raphaël was sent to cure the two of them, Tobit by removing the white patches from his eyes so that he might see God's light again, and Sarah daughter of Raguel by giving her in marriage to Tobias son of Tobit and by setting her free from the evil demon Asmodaeus."

intercourse by love. Top of those among the Dominations in charge of Venus is Anaël,[27] that is, he is invoked &1229 by the grace of God; it is by his grace that we are loved and love, are united to a fertile woman, and procreate offspring; then there is beauty itself, and charm.

The life of everything is presented to the Sun: over it presides the order of Archangels, that is, of principal messengers; all virtue is sent down from the Sun through the Moon; of these, Michaël is the Prince, that is, who is like God?—and there is nothing like the Sun, hence too it is described as, so to speak, alone.[28]

Mars provides [663]courage and boldness, otherwise we would be in permanent fear. The Powers[29] are in charge of its sphere; there is power[30] in courage, and courage is linked with power.[31] The Prince of the Powers is Samaël, that is, the hearing[32] of God; for power and courage is situated in the hearing of God. It is Jupiter who mingles and tempers everything, hence come faculties and powers; from him the order of the Principate is established in moderation and temperance. So the prince of these two is Sachiel, that is, the repose of God,[33] for it is in temperance and moderation that we acquire repose. The same Sachiel is responsible for times of tranquillity, peace and happiness.

But Saturn contributes steadfastness, and he too, almost alone, regulates the moistness and heat of others, and because of his coldness and dryness is regarded as the lord of death and the dead. Thrones guard him, because kingdoms are supported by him, and anything that has prolonged existence: a Throne is a resting place.[34] And so the Lord of this is called Cassiel,[35] that is, God's hope; prolonged existence brings hope and security.

The Seraphim (that is, the Burning Ones) rule the eighth sphere; there are so many of the lights of this sphere that seem to be on fire. But the Cherubim (that is, the Knowing Ones) rule the first heaven; &1230 who indeed truly know,

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[27] The Archangel that breathes life into the body, and is in charge of Venus, as mentioned here.

[28] "Michaël" in Hebrew actually means "Who is like God?" And there is a play here on the words "Sol" = Sun and "solus" = alone.

[29] "Potestates."

[30] "potentia."

[31] "potestas."

[32] "auditus"; Samuel's mother Hannah gave him this name in Hebrew "because I asked the Lord for him" (1 Samuel 1: 20; Vulgate: "eo quod a Domino postulasset eum") and the name has two components in Hebrew, the first meaning "hearing" and the second "God."

[33] "Dei quies." Sachiel is one of the Archangels, and also known as Zedkiel or Zedekiel.

[34] "sedes."

[35] Angel of harmony, balance, and serenity.

apart from those closest to God, who look upon Him?[36] But it is hard to reach the number of the intelligences, since all of heaven is intelligent, and a multitude does not always seem essential. If they are few, it looks inconsistent to have allotted afflictions to so many mortals in such a small space, but in such a wide one to have granted happiness to so few. So we must consider that an infinite multitude is not held within one order, not forty-four orders. But whatever their number, they surely should be held in honour; while they are much more worthy of reverence than parents, kings, and gods, whom we normally worship, they are not to be adored; and this is the greatest advantage of human wisdom, when we recognise and love and revere souls linked to bodies—but not the bodies themselves on their own.[37]

[36] In current Roman Catholic and Eastern Orthodox doctrine, seraphim rank above cherubim: "They are distinct from the cherubim who carry or veil God, and show the presence of His glory in the earthly sanctuary, whilst the seraphim stand before God as ministering servants in the heavenly court" (*Catholic Encyclopedia*); and G. Podskalsky, "Angel," *Oxford Dictionary of Byzantium* 1:97.

[37] The final sentence replaces a much shorter one in the 1550 and 1554 editions..

[663] &1230 Book XXI
On God and the Universe

So[1] far, we have spoken about the parts of the Universe and their accidents; what now remains is to talk on the nature of the whole, and on some hidden principles; then on God, who, being the author of everything, deservedly requires a place apart and a separate treatise. So making a start from higher up, we have shown that the air in the upper part, where it is not warmed by the reflected rays of the Sun, is cold. This must &1231 cast great doubt on the followers of Aristotle, who add that air is hot. But when things gradually change from one end point[2] to another, though they are situated quite far from one of them, yet they are even less affected by this quality of heat. And so the higher the part in which air exists, the colder it is, except when it has come very close to a tempered state through its lightness and rarefaction.

Hence since the air warms up because of the rays reflected from the earth, it will be colder in the upper part than in the middle. And so it is best to live in midway residences in winter, but in elevated ones in summer. In summer there is twice as much vapour, fatty and thick, from which dew is made. Hence fields are greatly fertilised[3] by dew, and it does not rise up, because of its thickness.

When it gets better concocted, as occurs in hot regions, it is condensed by the cold on top of the plants, and is called Manna.[4] So much of it is gathered in one day in the desert of Targa[5] of the population of Libya, particularly near the

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[1] The first (1550) edition opens with material which does not appear in the later editions till [A] on 1254 (1560), and underwent some revision then

[2] "terminus."

[3] "impinguantur."

[4] This is not precisely what the Old Testament says of "manna," which was described as having supported the children of Israel during forty years in the wilderness: "The manna looked like coriander seed, the colour of bdellium. The people went about collecting it to grind in handmills or pound in mortars; they cooked it in a pot and made it into cakes, which tasted like butter cakes. When dew fell on the camp at night, the manna would fall with it" (Numbers 11: 7–9).

[5] An extensive area in SW Libya was once so named; it is now named Fezzan.

town of Agadez,[6] that a pound of twenty-eight ounces is on sale for two asses.[7] Through its use they live in safety, though the air is pestilential. It is gathered on clear nights, both because they are cooler, and because the dew cannot convert to the matter of clouds; it is, as I said, condensed by cold. So when rain is generated, there cannot be severe cold; the vapour is caried away by heat, and compacted by cold. So there can be rain with cold; when heat is generated, it has to be active. So there is little or no manna on cloudy nights, much less still when there is rain: it melts. There are three kinds of it: the best is what is collected in leaves, the medium grade &1232 which is collected on branches, the worst is collected on the ground.

Thus the fattier part of the vapours passes over into dew; what rises up is condensed by cold in the thin air and turns to rain. In summer it does not rain much, because heat does less carrying away than it does drying; in our own neighbourhood, as the heat is weak, it attracts gradually to itself the vapours that are taken up by the dryness before turning into rain. Consequently, if there is rain, it comes suddenly; when the clouds have extended the lapse of time, they are removed by the Sun's dryness.

But not in winter—the vapour is not attracted, because the Sun is weak, and so there is clear weather; or if it is attracted, it is not attracted higher up, so that even if the misty air is attracted higher, the lightest part is the only one that rises, and it is not condensed, because the air is thick and the vapour thin; the air is thicker because it is cold. So since it is not condensed, snow comes on, for snow is the freezing of uncondensed vapour, on account of the thinness of its own substance, and the air's thickness. So snow occurs at a higher level than frost, and from thinner vapour; hence frost is colder than snow. This is why it kills trees and removes their eyes[8] [664]more than snow does, and this is also because frost arrives later. For snow only occurs in winter, because that thin substance does not easily freeze. But dew freezes easily, being earthy, and so frost arrives later than snow.

Why do I say "later"? The time for frost starts earlier and finishes later than that for snow. The evidence is that frost develops around the ground, because it develops in houses around wet walls; frost forms in winter instead of dew. Consequently neither snow nor frost turns to ice,[9] nor do they &1233 change into hail; vapour needs to condense to make hail and ice, but there is air in snow and frost, so neither snow nor frost while still in existence can pass over into ice or hail. Hail develops at a higher level than snow, both because in summer a higher level is needed where it can get cold than in winter (this was explained at the start),

[6] Agadès, now in Niger, some 600 km to the southwest of the border with Libya.

[7] A coin of small value, originally weighing one pound, but even in classical times reduced to near worthlessness.

[8] "excaecat."

[9] "gelascit."

and because in summer the vapours are carried higher up because of the thinness of the air, and their heat and subtlety, and the Sun's power. And in hail compression has to occur, to constrain it into ice. Hail sometimes occurs of such size that it matches large stones, and kills beasts of burden, and demolishes houses. In the ordinary way it can break, knock off, and ruin[10] tree fruit and crops. But generating hail without winds is not possible; if the air is thin, it is not cold, so that the vapour cannot freeze, if thick vapour cannot be condensed without winds. And for hail, vapour has to be condensed to prevent snow or frost forming, and has to freeze, in case water and rain form. Hence it is barely possible for snow and hail to form together. Either can be linked to rain, since what is not frozen, and is condensed, becomes rain, not hail; what is condensed while the air is too thin to prevent any contraction associates with snow as it does with rain. So it is clear that the utmost cold occurs with snow and hail—just as when it rains in winter, there is mild heat,[11] otherwise there would be snow.

But you will ask how snow can form on mountain tops, and &1234 [wrongly numbered 1230] how they come to be very cold, since reflection takes place there from the mountain. But it is no wonder that the utmost cold is right on the mountain top, because when the air becomes naturally extremely cold, still the place from which the rays are reflected is uneven, so that they are not reflected to the same place. It is also tapering,[12] and so there is little reflection; further, in itself it is naturally cold, being stony, and part of the mountain lies in shade. And the main point: the neighbourhood of the summit, being far removed from the valley bottom and level ground, is very cold. So since the air is carried along parallel with the winds that are blowing, the summits must be astonishingly chilled—we showed this in our *Problemata*.[13]

But when mists rise higher from a mountain ridge, though raised no more than two thousand paces from the ground, they are much more than this from ground level, since they started from the ridge. Similarly, if a mountain rises five thousand paces, clouds at seven thousand are sometimes hardly above ground level. Snow does then form, because of the excessive height of the mists, even in a warm winter, or hail in summer. A characteristic common to snowstorms, hail, and clouds is to develop in two ways: either through vapour risen at the same place, or vapour formed elsewhere, and carried there by the winds. Certainly wherever hail develops, it does not do so without wind, and mostly with a number of winds struggling with each other.

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[10] "prostrare": this is a present infinitive manufactured from the past participle "prostratus," of which the standard present infinitive is in fact "prosternere."

[11] "teporem."

[12] "angustus."

[13] In his *Problemata*, 1. 2 (*OO* 2: 621) Cardano speculates somewhat hesitantly about the cool air at mountain tops. This work of Cardano's was started in 1550 and details of its composition and publication can be found in Maclean, *De libris propriis*, M88, 88–89.

Water ascends higher with great difficulty, both because it is condensed, and because, being heavy, it moves downward of itself, if not constrained by the impact of winds. But this does happen to hail, because it only develops when condensed, &1235 so that very often it is dispersed by the sound of bells. Air carried upward by a slight impact prevents the condensation of vapour. But when vapours are condensed, they move down under the impact of gravity and of winds; in a place where they split the air, they get flatter and whiter, so that they appear to have a tonsure, and the idle crowd then supposes that the fall was due to priestly spells. When ignited vapour tears at condensed clouds with much force, lightning flashes develop, and thunder from their fall.

But when the mists containing snow are not compact, they cannot be torn with an impact; thus neither lightning nor thunder is heard while snow falls, nor in winter. But if in winter there are flashes, and thunder is heard, rain falls, not snow, and very often hail, as occurred in December in the years just past, and during fog. The reason is that hot vapour had warmed that district as it rose. Then rainstorms occur very little in winter, and are uncommon and brief in summer. In spring, as the following day removes more than the previous one has attracted (a later day is hotter in spring, and has a shorter night), it rains less for that reason than in autumn, but for longer than in summer, and more often than in winter.

This shows that when it has rained much in winter, the winter will be warm, and less healthy; if this occurs in summer, that the air is moist, and hence unhealthy; if in spring, it is a cold spring. It is in autumn that the heaviest and longest rainstorms come about, so that this is attributed to the rise of Arcturus, but erroneously—for since the Sun is still strong in autumn, many vapours are drawn upward, but when the following day has a &1236 longer night than the previous one, and the day is cooler too, vapour has to be condensed, and consequently descend. What had fallen is again attracted by the moistened ground, thus sticking to the earth's surface, and there is also something deeper that is contributed, so that not only rainstorms and showers but also cloudbursts[14] occur. This occurs especially when clouds brought by the winds from a damper place have provided the start of a rainstorm; otherwise, they are gradually condensed, and gradually increase. If they are brought from another place, they start suddenly being large. If the rains do not fall, this is for one of three reasons: either because they do not start, and then the autumn is wholly very dry; or because after falling at the start and the clouds [665]gathering again, the winds move them elsewhere, and then that autumn is windy; or because the heat is drier, and then it is pestilential, and leads to evil diseases.

So snow can develop on the mountains of Africa and Ethiopia, since vapour can be dragged higher from there, so that it is condensed by the air's coldness, and thus freezes and passes over into snow. It persists where the Sun does not

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[14] "nimbi."

reach, and among trees, and because of boulders. In Ethiopia, the southern parts of mountains lying in the southern part of Ethiopia, and the northern parts of mountains of the north are untouched by the Sun, especially when it approaches and is far away.[15]

In itself, snow is very white because of its air; ice is darker, because it forms from water, in which there is absolutely no air; hail is in the middle, being made from water, but water condensed from vapours, and so it is not free of air. So white hail is &1237 less cold, and occurs with milder winds, and comes down at a lower level. If dry and barely arid[16] vapour rises up (a rare event), a gap develops. For if you have made a dark patch in a picture, and stand far away, a gap will be seen at the patch, or darkness, because of the resemblance of the colour that is seen in the gap and in apertures.[17]

But to come back to snow: why is it usually seen less at the summit in summer than in the middle? There is no other explanation except that the summit is exposed to Sun that is melting the snows; the remaining parts, and especially those away from the Sun, are safe from it. With this seen, now let us explain first why there are some parts in the torrid zone that are habitable, and some not. The inhabited parts are where there are rivers, or where it rains. But parts that lack both advantages are totally uninhabited, apart from small markets, and nothing else, without places nearby, without dwellings,[18] and also badly off.[19] But why are these parts arid, but the others moist from showers? The explanation needs careful search. Since, as already mentioned, rain needs to occur, moist vapour must persist. It persists through not being dispersed by heat. With us, it does not persist, or rarely in summer, because gradually (as mentioned) it is exhausted through the Sun's weakness and the short nights. But in the torrid zone, when the Sun is overhead, with vast concerted power, a huge quantity of vapour arises, the Sun being so strong, and cannot be dispersed, both because the following night is long and because the vapour is plentiful. So it gathers and comes down as rain. For since a fire cannot disperse much water except over &1238 a very long time, what are we to say about the Sun's power, which is much inferior to a fire at drying? Again, through the quantity and thickness of the vapours, the solar rays

[15] This sounds as if the Equator ran through Ethiopia, and the Tropics were very close to it, but this is not the case, and Cardano knows this and presently remarks that Ethiopia is on the Tropic of Capricorn [in fact the Tropic of Cancer, Capricorn being the southern Tropic]; the Equator runs through the middle of to-day's Kenya, and south of Ethiopia.

[16] "siccus ac minimè aridus"—sense obscure.

[17] "cum nigram macula in pictura feceris, et procul statueris, videbitur macula hiatus seu tenebrae, ob coloris qui in hiatu ac foraminibus apparet similitudinem." Syntax and meaning unclear.

[18] "villae."

[19] "atque etiam malè."

cannot get in, and so only a portion of the upper vapours is consumed, the rest all persisting, and it comes down as rain. Though the Sun's power is quite sturdy, what had fallen is snatched up again, and something is contributed from the innermost bowels of the earth, or the sea, or rivers, or the adjacent mountains. Hence rain returns again on the same day, and often more of it. It persists in some places for forty days, in others for sixty, and in others even for three whole months. So strong winds have to be absent, and they are, because a vigorous Sun can dissolve a thin exhalation, but not a thick one. And if winds are present, there is such a strong steady reason for the generation of rain (as was mentioned), that though a clear sky opens two or three days, yet the day reverts at once to rainstorms. So with the Sun overhead, it rains in Ethiopia and India for three or four individual days; those are the names of the parts of the world on which the Sun impinges perpendicular and vertical.

But it is not clear whether it rains everywhere; there would not actually be deserts and sandy areas if it rained everywhere; they exist, so it does not rain everywhere. Thus it fails to rain in some place because the sea and rivers and mountains are far away. It has to rain in the mountains, otherwise the Sun's heat would convert them into sand. Then where the Sun pauses rather long, incessant showers fall; as it recedes, the earth dries up, because it is being more broken up than drawn together—as &1239 the heat is moderate, and attracts gradually, and what is attracted is dispersed—the dispersed thin vapour passes across into air, and thus firstly the air gets dry, and then the earth is dried by the air and the Sun.

Thus in the torrid zone, two contrary things befall what there is in that region. First, that with the Sun's approach rainstorms are created, and with its recession the earth dries up; so summer is wet, and winter dry. But here, summer is dry, with not much rain, and winter is rainy or snowy, and wet. The second thing, a consequence of the first, is this: on the Sun's approach, they get winter, but we get summer; from the Sun's furthest departure, they get summer, while we get winter. But in the island of St Thomas,[20] belonging to the King of Portugal, which lies under the celestial Equator, when the Sun is in the northern signs, the winds that blow are the so-called Auster, Sirochus, and Garbinus,[21] which bring rain, being wet. Boreas, Graecus, and Magister[22] (the names of these winds) do not blow there, so that they have two winters: when the Sun is on the equinoxes and overhead; and from March till August, there is cold with wind, and then it is Spring. When the Sun is in the southern signs, from the solstice,—that is, in

[20] The island is in the Virgin Islands.

[21] The South, SE, and SW winds, respectively: Mezzodi, Syrrocho and Garbino in a list of 1581 (see http://www.geog.port.ac.uk/webmap/hantsmap/hantsmap/cmprose.htm, accessed on 3 Mar. 2008).

[22] The North, NE, and NW winds: Tramontana, Griego, and Maistro in the list of the previous footnote.

December, January, February—it is summer.[23] Also, while it is in the southern signs before the solstice, the winter is longer. The furthest part, having plentiful rainstorms and yet being warmer, is reckoned as autumn. Thus the seasons are arranged in contrary order: spring precedes winter, and autumn precedes summer. And where there are not frequent rains, on the basis of the Sun's motion there will be &1240 eight seasons in the year: a twin spring with the Sun making for the equinoxes, and when it is moving away from there, two summers. Then with it moving towards the solstices, two autumns, and when they are over, the same number of winters, but not cold ones. Where waters are close by, and the air is free, only four seasons are encountered: two winters under the equinoxes, and between them a double spring, so people are right to mention the temperate and fortunate dwelling-place under the celestial Equator.

What goes on in our own districts does not need description; it is now appropriate to explain what has been mentioned, and what happens in Ethiopia, so that the winters are around the solstices, [666]since it is located on the tropic of Capricorn.[24]

So as the Sun is approaching under the celestial Equator, as I said, vapour is attracted in a body, and since it is so plentiful and lies between the earth and the Sun, it chills the air moderately, and moistens it vigorously; this condition is rightly called winter. So it starts at the time when the Sun is on their[25] summits. Hence winter occurs after the Sun's approach, and summer and clear skies from its departure, as we said. These events are greater in the mountains, and also more obvious than on the level. This makes clear that with the Sun resting around the same region (this is especially between Siene and Meroe),[26] rainstorms are so abundant that the rivers swell, and abandon their channels to irrigate the earth—hence flooding occurs.

Why then do these rains come on first at once after the summer solstice, and not earlier, since the signs[27] of the Twins, which start from 11th &1241 May, are at the same distance from the Equator as the signs of Cancer,[28] in which the Sun takes a pause from 11th June till 11th July? The explanation is that, since the earth is already dried by the prolonged retreat of the Sun, and attraction is not thriving till the Sun has imposed vigorous heat, it cannot do so till it has moved

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[23] The following nine sentences first appear in 1560. Instead of them, 1554 here has a passage of some eight sentences about St Thomas Isle of the West Indies.

[24] I.e. of Cancer; see also 220 (1560) in Book II for the same transposition of the names of the Tropics.

[25] "illorum"—but it is not clear what summits these are.

[26] Syene is now Aswan in Egypt, over 800 km up the river Nile from its mouth. Meroe is now a deserted settlement, but lay in what is now the Sudan, downstream of Khartoum, not far from Atbara.

[27] "partes"—signs of the zodiac.

[28] The zodiacal sign of the Crab.

round in the same line. This does not occur before the solstice for us. And this is why an intense summer does not happen for us before the solstice, and summer starts for that reason, and the behaviour of winter is similar; the start of perfection is always from the most perfect condition. But this takes place at the Sun's solstices, one moving towards heat and the remaining one towards cold; at these times the Sun is actually stationary. So vigorous attraction will not start till the Sun has reached the summer solstice, and so neither will the rains; the vapours that have been attracted will be destroyed previously by the air's dryness. Hence this rain starts in Ethiopia from the summer solstice, and persists for forty days. Why not continue till the Sun has reached the start of Libra?[29] The same explanation that is usually offered for the limits of summer meets the case: when the Sun has reached the middle of the Lion, it is already drying the earth, and gradually exerting attraction, so much that the rains stop too, with the consumption of the vapour. Thus when the Sun has moved on from the start of Cancer to the middle of the Lion, continuous showers occur in Ethiopia, and with the Sun situated at the top for them, winter comes on, because of the profusion of waters. And not when the Sun is on the Equator; though there it may also lift up the vapours and heaven may release water; however, since every five days it moves almost two degrees away from the Equator, the attraction &1242 is weakened in individual districts, so that there are no showers nor cloudbursts nor storms, but some rain. With the Sun approaching the tropic of Cancer,[30] it barely moves away one degree either side in forty days. Consequently there are rains and showers no longer, but cloudbursts and storms; as I said, lightning flashes occur in cloudbursts, because as I said, while there is rain it has to condense the clouds; but in a condensed cloud the sulphurous vapour is ignited, as in military artillery. And since it takes up more space in that condition, it breaks up the cloud with its enormous impact, and (as I said) nature does not tolerate two bodies occupying the same space; and so a compact cloud is disrupted by this impact, and the lightning glitters.

Consequently the cloud is suddenly shattered, and emits that well-known great noise called thunder, which makes many animals (especially sheep) and even some women abort. As the whole blast[31] cannot get out all at once, as occurs in military artillery, but some parts of it get out gradually yet rapidly (because the cloud is high up), and are shattered over a single period, the result is that thunder does not just emit a prolonged noise, like military artillery, with a reducing sound, but the main noise from thunder has various parts, so that even the portions of the cloud are disrupted one after another by the descending fire.

As lightning is fire, why does it descend, when it is fire's property to ascend? The cause is that the first impact arises from a more compact site; it sometimes

[29] The zodiacal sign of the Scales.

[30] See n. 24 above on Cardano's tendency to transpose the names of the tropics.

[31] "ignis."

happens that the more compact cloud is above rather than below, and this fits theory, because as I said, the higher part of the air is colder than the &1243 lower, particularly in summer, which is when lightning flashes especially occur. This is the way in which artillery tilted downward expels the ball below and the fire further down, since the initial impact is from the upper part.

It also sometimes happens that lightning strikes towards heaven, since a cloud is more rarefied above than below. This is a further reason why snow occurs without lightning, for the sulphurous vapour is not condensed so as to be capable of being ignited, and even if it is, as I said, it cannot create an impact in quite a rarefied cloud.

And why does this well-known fiery vapour always turn up among showers that are accompanied by winds? This is because there is something sulphurous present in the earth's surface, which is seized upon by the Sun's power in summer. And this is the third reason why when snow is falling, lightning flashes do not come down; the Sun's weak power cannot drag earthy vapour higher up. And how can it be ignited, though thinly distributed? While the vast power of the winds is driving away watery vapour, it drives the sulphurous portion to the bottom; and just as when the outside part of lime is lightly moistened and the inside is dried by the incessant motion of the winds, it is ignited by the contrariety of cold and humour, and finds the lower part more rarefied while bursting into flame, and comes down like the fire that is expelled towards the ground by tilted artillery.

Now in conclusion, a futher problem remains: when the Sun is at rest close to the tropic of Capricorn, or that of Cancer, why does it not evoke floods there too? Thus there will be storms in India and Ethiopia from the middle of December; these regions too extend &1244 to that circle.[32] So this should be mentioned, unless perhaps because then the Sun is closer to the earth, so that it prevents rains because of vigorous drying at perigee.[33] But if these rains only happen there, they are beyond the springs of the Nile; the river Nile, the largest in the Goian kingdom of Ethiopia (which is ruled by Prester John, called the Neguz in their own tongue), arises from two lakes, resembling seas from their size, at six [667]degrees—or a few more beyond the Equator towards the south, in Ptolemy's view—although he introduces the mountains of the Moon.

Moving on from there, it runs down from very lofty places with an enormous crash, and does this twice. These rough situations are called cataracts; they are the higher points of mountains from which the river runs down in vast foam. One of these is called the greater and the other the lesser. After this it expands like a huge lake, embracing seven hundred islands, of which the largest is called Meroe, about nine degrees beyond the tropic of Cancer towards the Equator; on

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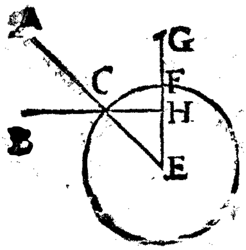
32 The Tropic of Cancer.

33 "in perigeo," i.e. at the point where it comes closest to the Earth, opposed to "apogee," the most distant point from Earth.

it there is a city of the same name.[34] Then coming together once more and returning to its bed, it makes its way into the sea by seven mouths; from its source till it reaches the sea, it proceeds straight from south to north.

The Nile has few tributaries, or none at all. But on the seventeenth of June, after the Sun has reached its apogee,[35] it starts to swell, moving out from its own bed. It floods and covers the land of Egypt, so that most wild beasts die, and beasts of burden and human beings protect themselves on higher places. This inundation increases for forty days, in fact until the Sun reaches the middle of the zodiacal sign of the &1245 Lion; then diminishing from that day for the same number of days, it leaves Egypt dry.

This is how these changes go on. But before seeking their explanation, we must look for the basis of inundations in general—there are other rivers that flood land, such as the Po[36] in Italy, and the Hister or Danube in Pannonia.[37] The cause of every inundation is either that the river banks are low, or that the water is plentiful, or that there is wind against the current (or even across it), or a high tide and backflow preventing the water running out into the sea. The banks get low when the earth splits. Excess of water occurs either through the wellspring swelling or the snow melting, or from rain. While winds are blowing against the water's current, they prevent its outflow, and hem it in, thus making the river swell—and the water even runs down sometimes from quite high banks. Any



wind does displace the water, because it either moves downward or straight on. Wind moving downward, as at AC, disturbs the water, for while it pushes it down towards E, the part occupying the space CE occupies EF, so the part EF rises to FG, and thus the water swells and overflows. But if the wind proceeds straight on from BC, then because the point F is higher than H, the water is driven along; water is rounded, as you see in pitchers. The reason that we can see rivers and lakes from a distance is either that we are looking from a height and so can see the water, or are looking from the level, and &1246 we see it too, since water is rounded.[38] It is clear that the straight movement is double: one component is the mathematical one, which takes place along

[34] On Meroe see n. 26 above.

[35] See n. 33 above.

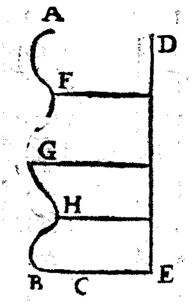
[36] "Eridanus"; this is the Po, in northern Italy. For the earlier applications of this river name, see *OCD*.

[37] Roughly equivalent to eastern Austria with western Hungary.

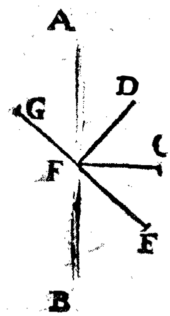
[38] The diagram suggests that E is the earth's centre and the water surface vast, but the "roundedness" ("aqua rotunda est") in pitchers would be expected to be the meniscus. Archimedes has, in Prop. 2 of his treatise *On Floating Bodies*, I, that : "the surface of any fluid at rest is the surface of a sphere the centre of which is the same as the centre of the earth" (Archimedes, *Works*, trans. Heath, 173).

the shorter line, and this occurs from impact,[39] and this is how the winds are moved; the other is in accord with nature, and this is the way water moves along the circumference of a circle. So although water moves in a circular motion and wind moves along straight, there must be a disturbance of the water from any wind.

The roundedness of the water is the cause of storms. When the wind blows from the side or against the motion of the water, and is a big wind, there will be a flood, and where there is breadth, a storm. On a river there is always a wind from some direction, either against the flow, or from the side, because the flow twists sinuously, as snakes do. Hence there will be a flood somewhere, unless the wind



is quite gentle or the water is scanty. For example, let ABC be a river, and let a wind blow from DE; it will blow transversely at FGH, and if there is much water, it will produce a flood, but otherwise not. But wind from D towards C, being against the water's motion, will inevitably produce a flood. So this is why when the wind blows there is a flood in some places, in others the rivers dry up, so there is a greater flood, either because of the copious waters or the strong wind, or because it comes from above and drives the water along by its force, and behaves as if digging into and draining the water. The basis for storms &1247 and their magnitude is evidently the profusion of water, so that a storm is greater on the sea than in lakes, and in lakes than in rivers, and in great rivers than in small ones.



So when there is a single wind, advancing straight as along the line BC in the previous figure, it will not be submerged. But if it is oblique, that is, comes down from above, then it rolls along a huge quantity of water and creates great peril. And if the two are contrary, like AF and BF, the ship will be submerged, since it will be unable to make progress with one of these[40] striving against it; and if the ship is driven from C to F by winds beating against its sides, it will be overturned. It is better for the ship to be driven from D to AF, where the wind AF is stronger than BF; a ship is always safer that is carried along with the stronger wind than one moving against it.

And if there are three winds, AF, BF, and EF, and one of them comes from above, and AF is the stronger, it is inevitable that the ship will sink, since it cannot make way with DF, because it was being overturned by the wind from EF. Nor can it make way with EF, for it will be overturned by AF; nor can it with GF, since FE resists. What also happens in the [668]Ocean is that because of the

[39] "impetus."

[40] Reading "illorum" with 1554; the "lo" appears to be absent in 1560.

tide, individual winds take on the behaviour[41] of two winds, with the wind above and the tide below tossing the ship about, but not so perilously. We have now described the dangerous storms and how to escape from them.

Just as inundations are transient lakes, so lakes are permanent inundations. So &1248 lakes come into existence from five coinciding causes. The first is for a river to overflow onto a neighbourhood—big lakes from big rivers, such as Lake Constance,[42] which is very large on account of the Rhine, Lake Geneva[43] on account of the Rhone, Lake Verbano[44] on account of the Ticino—and little ones from small streams, like the Eupilus[45] in Italy. The water needs to be collected from the height of mountains or hills, and so every lake lies between mountains or hills, otherwise the collected water would pour over and be dispersed. Next, the position needs to be between sides and lower than the bed of the river; if it is higher, when the river dries up at times, as often occurs, the lake will dry up, and now there will be no lake, but a marsh or bog. In fact, it is not a lake when it dries out often, and if it has not enough water to flow all the time, and is regularly disturbed by storms. When it is at rest, it is a marsh, not a lake.

It is also essential for the bank to be higher at the side opposite where the river runs in, otherwise it will actually all run out, and there will be an inundation, not a lake. Finally, the low-lying area must be kept narrow and the river must run out—for if it had not done so, the water will be spoilt, and there will be a sea, not a lake, even if it does display a tide and storms. So no river runs out of the sea; even if it did so, it is out of proportion to it.[46]

You have learnt the distinguishing points of lakes and the sea and swamps (or marshes) and inundations. Now let us return to the causes of the Nile's inundations. The reason is that that storm already mentioned makes its start in Ethiopia on the eleventh of June; the river swells at once, as still occurs with us, because there is a great supply of water, and the Nile &1249 overflows onto the fields. It is no obstacle that Ethiopia is far away from Egypt; if the sea swells in the midst of the reflux of water because of the tide, as mentioned before (a flux of water and a swelling are different; a swelling moves along with pressure making the components follow upon each other from endpoint to endpoint), it is no wonder that though the Nile flows slowly, over four days it can swell from one

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[41] "ratio." This sentence is modified in 1560, the earlier version not mentioning the tide.

[42] Or the Bodensee, on the boundary of Germany, Switzerland, and France; it is on the course of the river Rhine.

[43] On the border of Switzerland and France, and on the course of the river Rhone.

[44] Now Lago Maggiore, some 100 km NW of Milan in northern Italy. The river Ticino flows from it.

[45] Eupilis [*sic*] was the name of a small Italian lake, east of Como and adjacent to Milan.

[46] I.e. to the sea: "etsi exeat, non est illi proportione respondens."

endpoint to another; if you squeeze a bottle from one of its extremities, you will see it swell in the rest, without movement.

Then as the rain stops and the Nile unloads itself all the time into the sea, it thins out again and returns to its place. There is perhaps some contribution too from the fact that as we said, the Southern Ocean's waters are carried to the south over three or four months, with the result that then the Nile's springs are hemmed in, while the excess water runs over, and the Nile is made to rise and leave its bed. I did explain above that sweet water is continuous with salty.[47] In an excellent conclusion, the result is that these rains accompany the Sun: first of all, the salty water picked up from the sea is changed into sweet, and the wheel comes full circle,[48] with so many rivers emptying themselves into the sea, their sweet water turning into salty.

Thus if there needs to be an even distribution, capable of lasting for ever, there has to be a great deal of water from rainfall, to match the loss from all the rivers discharging into the sea. The second cause is that the air itself gets temperate, and so the region is habitable. Thirdly, that the ground should be perfused with moisture and abound with fruit and crops, so that animals and human beings can live in it, and that no great &1250 part of the earth should pass away into uselessness—it was shown previously, on contrary reasoning, that ground is cultivated even at the Poles.[49] Fourthly, to prevent the drying earth breaking up in its middle, and thus its total loss, while God had regarded the district[50] as neglected. The reason for all this, and other circumstances too, is for mists to accompany the Sun nearly all the time.

And it is not the case that vapour is conserved long enough for the Sun to move from the zodiacal sign of Gemini into Cancer, but the air just gets moist in the meantime; the previous day assists the following one by scattering water while the Sun is in Cancer. So this is why in the wide Atlantic, a very thick cloud is seen on the summit of the mountain called Sierra Leone,[51] incessant lighting is always flashing, and the thunder is heard fifty miles away; since the Sun's heat and the mountain's moisture are always active there, they create a permanent cloud. So the mountain must always be very moist, aided in this by the sea nearby, as the mountain does not simply earn its name as a mountain, but as it puts out roots into the sea, it is more a promontory.

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[47] "dulces aquas salsis continuari."

[48] "redditque vices."

[49] But this is not what Cardano wrote in Book XI above at 805 (1560): "There cannot be populous cities under the poles, since the ground is sterile, and the transport of crops is difficult."

[50] "partem."

[51] This seems likely to be Tenerife (3,718 m), a lofty isolated peak out in the Atlantic off the west coast of Africa, rather than Sierra Leone, in West Africa, which has a substantial coastal plain.

It can thus be seen, as has become known in our time, that the earth is not surrounded by the Ocean, but the Ocean is a sort of lake established between the lands, with on one side our inhabitable region, on the other Nortica,[52] Brazil at midday, and America to the north. In the Ocean itself are islands everywhere, an incredible number, said to exceed ten thousand.[53] And so the sea is a lake of the whole land, the land is not an island in the sea. As the islands abound in water, they provide evidence that it &1251 is not generated in them, but seeps through—how could it come about that Ireland has fifteen rivers, unless they took their origin from waters cleansed by the sea? Fresh water is held not just in these islands, but in very small ones, such as the one situated three degrees beyond the Equator, about two thousand miles away from any land, eight miles in length and four in width, all verdant and gushing with much fresh water.[54] The water has to spring up, since the island is the summit of a mountain; the mountain, surrounded by sea, freshens salt water by filtering it.[55] There are birds there of various kinds which used readily to allow themselves to be captured, being unaware of man's traps. So where did they come from? — they could not fly across such a distance, nor be generated from rotting matter. Either it was once inhabited, and the birds were carried across, then later it stopped being inhabited, because of fear, or a rise in the sea level. Alternatively, when ships passed, birds got off them and started their kind in this safe place; even now, the Spaniards disembark pigs in desert islands, so as even to be of use on some occasion.

There are three elements:[56] the [669]most dense is earth, the next is water, and air is the most rarefied; they are all cold. But air, being rarefied, is found to be less cold. Being next to heaven, it grows marvellously rarefied because of its perpetual movement, and this air is called aether, so little cold because of its rarefaction that it is closest to a tempered state.[57]

As heaven is much thinner than the aether, it is very temperate, either simply or among all bodies. In fact it will be eternal in the simple sense, as Aristotle considers; &1252 if it is like that just among the rest of the bodies, it will itself sometime have an end, as our law holds, and we have spoken on this in our books

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52 Not identified.

53 The 1554 edition makes the estimate 20,000.

54 The island named Ascension in the Atlantic fits this description moderately well, being about 8° south of the Equator, and about 15 km (9.3 miles) in latitude by 10 km (6.3 miles) in longitude.

55 "percolando."

56 In Book II at 74–90 (1560) Cardano in a complex argument maintains that fire is not an element, being only air heated up, and that there are only three elements: earth, air, and water.

57 "temperamentum."

De arcanis aeternitatis.[58] But we have explained above that both light and illumination are hot. So the substance of heaven is very thin—not all alike, but as one light is clearer than another light, so its substance is also thinner. Anything not in itself eternal is propagated, in some cases as substance, in others as accident. Again, some things propagate by generating something like themselves and indeed the same in species, as a horse generates a horse; others, something like themselves but not the same, as light generates illumination. Nature is in fact entitled to pity:[59] unable in the individual case to preserve for ever, it restores by generation. After anything has been born, it cannot go back any more; it would be eternal. The part of eternity that has reason includes unlimited time—just as if in a hundred years the same daybook kept returning, it would be as good as immortal. But it would not be immortal; eternity includes any time you wish, without limit. And anything multiplied by the infinite is infinite. There is also another greater danger here, since what is generated has to be generated from some matter—for if it cannot be generated from any matter, either something will be generated which cannot be generated (this contains a contradiction) or it will be generated without matter, and will not be a composite.[60] Matter then is something from which what should be generated gets generated. So long as it has been generated and persists, its potentiality has come to a halt and been converted into actuality. So either another potentiality has been left in the same matter (and so while it is present, generation can go on afresh, &1253 which is impossible; what is being generated is not in the same matter), or that potentiality has been left behind in other matter, or part of the matter.

And so let it be generated at that time; since this is now so, these two will now be one, from our supposition, and it will still be possible for one to be corrupted and the other to persist, and thus to exist and not exist, to be corrupted and not corrupted, and be one body in two places, and other gross absurdities without number. What is also absurd is this, for a corrupted potentiality after its generation to return to the same potentiality after being corrupted—it will actually be a potentiality of a potentiality, and can only be generated in the same matter, which is quite ridiculous, since it is dispersed into the tiniest parts, and being continuous, never returns to the same state; and if it were like that, it could not be diffused everywhere.

And so what is generated once cannot possibly return again. But this is not impossible as a similar thing. Of things that are generated, some multiply late and not much, like animals and plants; others do it very fast, but do not produce

[58] On this work see n. to 5 (1560) in Book I., and note that the original reader could not easily consult the work, since it was not published in printed form until the *Opera Omnia* of 1663.

[59] "Miserta enim natura"—"miserta" is a late and irregular derivative of "misereo" or "misereor," "I feel pity."

[60] I.e. Form plus Matter.

much, like fire—fire generates fire instantly, and that fire generates another, and in this way grows huge if there is no lack of matter. Bodies are propagated to infinity, then, because there is finite space in the world.[61] But simple things do this rather fast, and so do the less perfect creatures among the composites, such as the flies and worms, and among these, those that are the most worthless products of their parents, such as mice and rabbits; according as each creature is more perfect, it multiplies less, and later on; and what is perfect does not do it at all.

Light is not a body, but emerges from a body, so it generates its own like, but not the same &1254 in variety,[62] nor is what is produced capable of generating another. However, its propagation is infinite, since what is generated is not a substance. For when the Sun rises, its varieties[63] are innumerable (I mean those of light, not of the Sun). Whatever is generated like this is at once corrupted, through itself. Since an intellect is a substance, but one without a body, it is multiplied very fast endlessly; all the audience understand, and if they come forward, those who hear would understand, and others would do so just as much. So an intellect is propagated an infinite number of times,[64] provided there is no obstacle.

The same principle[65] applies to all substances that understand, but not in the same way; as has been said, our intellect is private.[66] [A] And intellects are not subject to the passage of time,[67] but picture the space in which they persist, and call it time.[68] It is like the centre in a circle; it relates[69] to each part of the circle, and if the circle moves, the centre stays unmoving, as time[70] stays unmoving in passing time[71] and in eternal time.[72] Time,[73] then, is not extended, nor does it flow, but it remains eternal.

Some people have felt that it follows that time is bounded by a circle, but enough has been said on this in the books *De arcanis aeternitatis.*[74] So whether

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[61] "orbis."

[62] "non autem specie idem."

[63] "species."

[64] "infinities."

[65] "ratio."

[66] "umbratilis": i.e. operating in the shade or in retirement or at home, contemplative, private.

[67] "tempus," here translated as "the passage of time."

[68] "aevum."

[69] "correspondet."

[70] "aevum."

[71] "in tempore."

[72] "in tempore sempiterno."

[73] "aevum."

[74] See n. 58 above and n. in Book I to 5 (1560). In chap. 8 of this work (*OO* 10: 13–14; M44 in Maclean, *De libris propriis*) Cardano describes circular processes over time: poverty leads to industry and then to riches; riches prompt ambition and envy, then odium, and the successors of the rich relapse through extravagance into poverty once

time[75] is comparable to passing time[76] or not, it is without division. I know the Latinists mean something different by this name, but we have set out what we wish; realities, not names, are under discussion here. This time[77] in which intellects continue must be either made or eternal; because what exists among eternal things exists of necessity, but what does not, cannot exist. For mortal &1255 nature is not more capable of immortality than the immortal is of mortality.[78] God is something better than anything, and is neither in time[79] nor in passing time.[80] Eternity is what is in itself stable; what runs forth and remains is time;[81] what does not remain, and flows, is passing time.[82] So since the universe is seen to remain, it is in time,[83] and passing time is in the universe. The best part of the universe is called paradise, that is, a planted garden, and a very delightful place, and one of pleasures.[84] There are two: a heavenly one of the blessed, and an earthly one. Passing over this, the island of Ceylon not far from Calicut is regarded as a paradise; it actually is the most pleasant place on the globe, for the healthiness of its air, the longevity (people reach 150 years there), the springs, the woods, the meadows, the crops, the fruit, the beasts, the elephants, the fish, the perfumes, the pearls, the gemstones, the gold and silver. This is the most outstanding place in the world, but not in the universe—the best of those here below, the worst of those that are situated above.

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more. Geometry is abandoned if pursued beyond usefulness, then taken up again later. Military discipline tightens in war and brings on its own relaxation with peace. But he does not there discuss the nature of time. In chap. 11 (*OO* 10: 17–21) he describes in great numerical detail the historic duration of empires, religious dominances, etc., maintaining that it is limited by significant numerical values attuned to the divine wisdom, and citing Plato several times, but not clearly stating any cyclic aspect. On the numerology in Cardano's thought, Maclean remarks that "Cardano is very close to the occult tradition in this feature of his writing; he shows the same tendency to create apparently arbitrary subsets and the same use of numerology as a heuristic device that permits the inquirer to postulate correspondences between classes of similar number" (Maclean, "Interpretation of Natural Signs," 242).

75 "aevum."

76 "tempus."

77 "aevum."

78 The following eight sentences first appear in 1554

79 "aevum."

80 "tempus."

81 "aevum."

82 "tempus."

83 "aevum."

84 The original Greek word (παράδεισος) was probably of Oriental origin (*Liddell&S*). It was first used by Xenophon in reference to the parks of the Persian kings and nobles, and was subsequently applied in the New Testament to the abode of the blessed (Luke 23: 43).

In between are some movements, which we call actions. There are three sorts of actions. The first is that from body to body, and is called a change.[85] The second is an inflow;[86] it proceeds into a body, but not from a body, on some hidden [670] principle. The third is the one that does not happen from the body nor in it, but in the mind,[87] and is called inspiration.[88] In every change, what plays the active part[89] is exposed to corruption. Inflow takes place from an immortal body, but inspiration from something immortal, yet not a body. And in these respects, these three differ from each other. Also, inspiration instructs, but inflow impels. The question whether the centre of the heavens is the same as that of the &1256 infinite universe is one that looks back to the books *De arcanis aeternitatis.*[90] In this one context itself, it is entirely necessary for there to be some God;[91] the universe's order cannot exist without a controller to run it, since if matter were controlled just by chance, it could not preserve the long-term sequence of things.[92] An arrangement so choice, so perfect, so suited to every purpose was totally in need of a craftsman not merely as judicious but also as very wise as God is. There is also an arrangement in every sort of cause which can reach no one other than God. And these three lines of thought[93] show conclusively not only that God exists but also that He is very wise, and is omniscient.[94] There is also much to persuade us of this—as one instance, the prodigies that reveal the future, which can only start from Him who knows what is to come; and as another instance, the origin of the human mind, which stems from some better

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85 "mutatio."

86 "influxus."

87 "animus."

88 "afflatus."

89 "quod agit."

90 Both 1554 and 1560 read here: "An verò coelorum idem sit centrum, an mundi infiniti . . ." but I have translated as if the reading were ". . . ac mundi infiniti." I have not traced any reference in *On the Secrets of Eternity* (see n. in Book I to 5 [1560], and nn. 58 and 74 to the present book) to the question specified here by Cardano.

91 The material of the following ten sentences first appears in 1554

92 Boethius, in prison and under sentence, thought similarly: "I could never believe that events of such regularity are due to the haphazards of chance. In fact I know that God the Creator watches over His creation. The day will never come that sees me abandon the truth of this belief" (*The Consolation of Philosophy*, trans. V. E. Watts [Harmondsworth: Penguin Books, 1969], Book 1: 50).

93 "rationes."

94 As Plato's Timaeus remarks in a similar vein, "For which reason, when God was framing the universe, he put intelligence in soul, and soul in body, that he might be the creator of a work which was by nature fairest and best" (Plato, *Timaeus*, trans. B. Jowett, 306).

craftsman—there is nothing better than a mind that understands everything.[95] And the consciousness of crimes that torments human beings, as if it were a fear naturally implanted in us, and a reverence for some better craftsman and king. Without any divine power,[96] alliances of cities would not be so long-lasting, nor would those who infringe them be liable to punishment by divine power. Differ though they may about the essence of God, in everyone there is embedded by general consent a concept and a worship of God, and this embedded by the Earth's memory. Again, the distinction between the honourable and the disgraceful, between good and bad, between virtue and vice, and also such a large sequence and marvellous array of the numbers take their origin from some primary mind, from some primary good, from some primary order.

&1257 All this is so numerous and so great that it not only shows that God exists, but also His characteristics and greatness. And if He does not look after each thing, since there are no things except individual ones, with individual things passing away the species too will perish. So it may be that individual things are supported by some order of the universe that we call Fate—or if not, the species will be capable of re-establishment from decay. The more likely of these alternatives is that everything continues through divine acquaintance with individual things in an order of the universe, since for philosophers it is ludicrous that species should pass away.

So God knows everything. But what determines lotteries?[97]—is it from Him? Not at all, but from some inspiration. However, our law states that lotteries are introduced and controlled by God. It is legitimate to use them to avoid abuse or offence when there is a struggle between rivals. An important sort is prediction from the earth,[98] surely built up on a marvellous basis, about which famous books are circulated under the name of Peter d'Abano.[99] And though friends of ours have done well in games of chance by using these, whether through confidence, or their own star for divination, or with the assistance of demons, nevertheless we have set out the inconsistency of all these in the fourth book on *Wisdom*.[100] And Diogenes[101] used to say: "When I look upon this race of prophets or

[95] Reading "quòd nihil non intelligat" with 1559, not the "quòd non intelligat" of 1554 and 1560. This section is not present in the 1550 edition.

[96] "numen."

[97] "sortes"; might also mean "destinies."

[98] "geomantica."

[99] On Peter or Petrus d'Abano, see n. to 246 (1560) in Book III.

[100] *De Sapientia* was originally published in 1544 (Maclean, *De libris propriis*, M47).

[101] Diogenes (c. 400–325 B.C.) was a Greek philosopher, founder of the Cynic sect, who lived in extreme self-imposed poverty in Athens and had a caustic wit (*OCD*).

predictors of the future, I think that human beings differ little from beasts; while physicians and painters differ little from gods."[102]

This is what we have said about the universal nature of things, not so as to cover most or a large part of them, but so as to explain, so to speak, examples, seeds, and principles of them all. In fact, if anyone grasps this, that what his mind is not strong enough &1258 to follow and what he supposes exists through extraordinary skill can be done by nature quite easily and, if I may say so, without craftsmanship, then he will not just stop marvelling, and will learn a great deal from a single instance. He will also pass across from nature's works to its skill,[103] and will himself without much exertion construct works that others will admire. Let one such example do duty for a very large number.

You can see butterfly wings, how beautifully and precisely they are marked out with colours? Then the hides of leopards, panthers, cats, and so many other animals,[104] which at the present day our so intelligent technique is starting to imitate, while people are dyeing with a purple hue the skins of those weasels called variegated from their motleyness—a discovery not only pleasing but also healthy. But I return to my theme. What is to be said about so many kinds of flower, so highly developed that not even a notable painter using the utmost care could reproduce them? What then is to be said on whether things that appear to relate properly to the power of sensation (and a very pure one) will have been created by nature—nature the craftsman devoid of intellect and power of sensation—or could be so? Or whether the carefulness of the supreme craftsman will be intended for such small and numerous things? Will he pick out for us the cyclamen flowers, the triple flowers of Jupiter,[105] those of cotton, of iris, of meadow saffron,[106] heather, henbane, and so many other herbs? Will he pick out for us stems of white hellebore, or finally the whole peony? Perish the thought![107] But understand the way in which such a masterpiece can be made without any skill. Things that chance has mixed up, however they are distinguished by colour, and without any plan, whether they increase or are equally divided or are inflated, display &1259 a form marked out with colours and embellished in detail and coloured quite beautifully. Thus butterfly wings and flower leaves are divided,

[102] Diogenes Laertius wrote, "He used also to say that when he saw physicians, philosophers and pilots at their work, he deemed man the most intelligent of all animals; but when again he saw interpreters of dreams and diviners, and those who attended to them, or those who were puffed up with the conceit of wealth, he thought no animal more silly" (*Lives of Eminent Philosophers*, 6. 24; Loeb 2: 27).

[103] "à naturae operibus ad artem traducens"; "traduco" is classically a transitive verb, and so the translation given here is speculative.

[104] The rest of this sentence with the subsequent one first appear in 1554.

[105] *Lychnis flos-jovis*, a pink perennial flower.

[106] "colchicum."

[107] "Absit."

and increase, and swell like glass vessels. When a lump is marked with white, as it were incidentally, and inflated, it produces these colours separated by equal intervals. Now you see that if anyone wants to make a painted panel, and one variegated with mosaic work, using colours mixed into the mass by chance, and the mass is split transversely into equal layers, the hardened slices will reproduce the form of a very beautiful panel, and will make the work everlasting, since they does not wash out like colours. So you see how in these a likeness of the universe is glowing; many things can come from one, unequals from an equal, contrived things from chance ones, ordered things from disorderly ones—similarly, with an easy even-handedness, so much comes forth from the one God, supreme and trustworthy craftsman of everything.[108] And from a unity a pair is seen to proceed first, as can be seen in the heavens, and a single thing cannot exist so simply that it is impossible to shape, and even ponder, two primary motions in it. But with this I will deal elsewhere.

It is not only what is hidden in forms but what is hidden in numbers that has a cause. For instance, the fact that in the Moluccas there is a richer and more successful production of cloves in a four-year cycle. The waters of hot baths [671] deteriorate over the same cycle; they are supposed to get harmful on the intercalary days.[109] There is also a kind of fever known to everyone, which earned its name from this cycle.[110] &1260 Those who attribute this to the power of the stars make Saturn responsible for it, and leave behind a greater uncertainty than they resolve: that is, what connection the stars have with a quartan cycle of days or of years. It would be better to consider the sequence of things themselves, which is carried on in a triple order: beginning, middle, and end; or imperfect, perfect, and complete. Or positive, comparative, and superlative. Since these steps are present in everything, good or bad, if the sequence recurs the fourth will be most like the first, the fifth like the second, the sixth like the third, and again the fourth like the seventh, and so successively. Thus the quartan cycle will become prominent, and its cause very clear—a cause which some people used to marvel at, for being superstitious, while others used to go over it at great length, for instance that in cloves their power has to be weak during the first year, better in the second, excellent in the third, in the fourth it gets exhausted again, otherwise its virtue would be endless. Similarly, in the waters of hot baths the virtue is of no use in the first year, good in the second, excellent in the third, of no use again in the fourth. People call it unhealthy and harmful, and when it does no good, it does a good deal of harm. If you look at sea waves too, first of all they increase,

[108] The following two sentences appear first in 1560.

[109] These are additional days added to certain (leap) years to match the civil year's length better to that of the sidereal year. Their name in the Julian calendar ("bisextilis") was chosen because the day that was doubled was *VI* Cal. Mart. (24 Feb.), and this happened every four years.

[110] Evidently quartan malaria, with a cycle of four days, i.e. it recurs every *three* days.

then they roar after reaching their crest, and presently decline, and return again in the same order—so that I would dare to say that everything that arises from great causes is restrained by this order. But let us apply our mind only to issues in which this order produces individual days or years instead of individual steps; then when three years or days are required, a four-period cycle is declared by reverting. Things that alternately collapse &1261 and are completed follow a tertian cycle: those that alter little or not at all, a daily one—and this is the most obvious reason for such a challenging problem.

Now the discussion must move in another direction: will you in fact ask why it is that if God is the author of everything, bad outdoes good, in speed, ease, frequency, magnitude? We come to grief and are disabled in an hour—indeed in a moment; to get enriched, to be healed, takes a long time. A vast evil arrives by chance, in a word; we are hardly kept safe by many friends and by their assistance. To sum up: so many calamities, griefs, pain, disease, dishonour, unrequited love, fear, poverty—and just one single good thing: not to be in need. Hence the Epicureans appear to have been right to hold that the absence of pain[111] is the aim for good men.[112]

What pleasure can be matched in magnitude to torture, what hope to fear, what happiness to bereavement, what agreeableness to imprisonment, what health to disease, or what wealth to the burdens of poverty, what honour to contempt or derision? Finally, there is that notorious last of all things, death, and even the joys of a thousand lives cannot be compared to its contemplation; it has this advantage, that it puts an end to the other griefs. Just as we detest death, we love our sons, as having become our other selves[113]—the only help, so to speak, against that inevitable end; they are a product of us, and preserve our likeness,[114] and reproduce ourselves. Consequently we love them more than we do prostitutes, even if more of our seed is destroyed for the sake of sons. The Craftsman made sex for the sake of sons more pleasant, because the bodies are mixed together, and what stimulates is very intimate, and with minimal distress; accordingly, &1262 though titillation is of a kind with itching, feeling it is much more pleasant. So when this was discovered, it contributed as a primary cause to the lasting future of animate things.[115]

In the conduct of affairs, the cause, the principle and the opportunity differ, and not just in nature: we say that the cause of Alexander's moving across to

[111] "indolentia."

[112] On Epicurus, see n. at 1221 (1560) in Book XIX..

[113] "ut nos alios factos amamus."

[114] "species."

[115] "perpetuitati animantium prima causa consuluit."

Asia[116] was the easy triumph of the Athenians over Artaxerxes[117] and Xerxes;[118] then the expedition of Agesilaus;[119] on these Alexander built his hopes.

A principle is what kings use to hide the suggestion of greed and ambition: for instance, the Persians crossing over into Greece, and the slaughter of the Persian envoys which was committed by the Macedonians.[120] An opportunity was Philip's death, leaving behind him warlike armies and a Greece worn out by disasters,[121] with the result that all his people sided with Alexander, through gratitude or fear. But God is different, being the cause, origin, source, and principle of all things in the universe. He is the whole immensity, and the utmost perfection, and contemplates nothing but Himself. He illuminates this world and that, and whatever is within the limit of the spheres, with such light and clearness that only He could capture it—unmoving, and without changeability, and no mortal could endure His splendour even for a moment, or gaze upon His brightness. You would more easily tolerate the summertime midday Sun in your eyes all year than as a human being you could study with your intellect the light of God for a portion of small time.[122] Yet on being carried towards it, one is very blest for just a moment; this is actually the ecstasy granted only to the &1263 honest and wise, better than any human happiness. It is of very rarefied substance, and consequently is always at rest—for things that are very subtle are either in constant motion, like the heavens, or ever at rest, like the intellect. God, however, is not an intellect, but something much better, more blessed, more potent, more worthy than an intellect.

You ask, "What is He, then?" If I knew, I would be God—for there is no one who knows God, and no one is aware of what He is, except God alone. Since we do not know what He is, much less is it granted to us to know his proper name. But He is not one of the remaining principles, since neither God nor they have any name, but we make use of names applied in accord with the view we

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[116] Alexander the Great, king of Macedon, started his vast campaign of invading Asia by crossing the Hellespont in 336 B.C.

[117] Probably Artaxerxes I, King of Persia, son of Xerxes, who in B.C. 449 made the Peace of Callias with Athens. This was reckoned sometimes more of a Persian success than an Athenian one (*OCD*).

[118] King of Persia, famously defeated by the Athenians at the sea battle of Salamis in 480 B.C.

[119] Spartan king who in 395 B.C. overran Phrygia in Asia Minor, defeating the Persian general Tissaphernes.

[120] Alexander I of Macedon (not Alexander the Great) cunningly arranged the slaughter of visiting Persian envoys around 480 B.C., by replacing the attractive women at a banquet by men dressed as women, who then killed the guests, and Alexander subsequently managed to hush up the murder (Herodotus, *Histories*, 5. 18–19).

[121] On the death of Philip II of Macedon in 323 B.C., his son Alexander the Great inherited his father's war machine.

[122] "temporis exigui parte."

have adopted of them, either of their power or their distinction or their standing. Again, much has been fabricated by wicked people who have dared to trifle even about God, as they might about any of us. But names are adopted from the nature, powers, and properties of things as we know them. We have explained that the souls in heaven, and their nature, and (much more so) the nature of God above are unknown in every part to our intellect, and so in what way will there be any name for the gods, or will it possible to attach one to them?

All[123] this detailed and extensive account of Subtlety would be enough for those dealing with it according to sorts and species; the actual details would not be going to reach any end, and yet are included under these headings. What is set down here by way of examples is inserted, some of it to enlarge experience,[124] some since it would look more divorced from reality, &1264 some because it is infrequent, some because it is difficult. One can move across from these to others [672]of the same kind, working from resemblance, and contrary, and consequences, and from the constituents of explanation.[125] What is larger and more notable from its composition is obtained from the details, but with more effort. Let us therefore put a limit to it.

So Thou, most high God, from whom all good proceeds, whose nod moves everything, whose power is confined by no limits, infinite brightness, who alone providest true illumination, alone art truly eternal, complete in Thyself, known only to Thyself, whose wisdom exceeds all thought, single and without compeer, outside whom there is nothing, who hast directed me like an earthworm in the shade of knowledge, to whom I owe anything written here that is true—the mistakes are the outcome of my ambition, rashness, and haste—do Thou pardon me; and by illuminating my mind in accord with Thy tireless generosity, turn it to better things. Since Thou hast need of nothing, and I could not add anything that the heavens and the powers of the heavens, matter, and earth make, and the whole of the parts of the universe itself, I offer Thee perpetual gratitude for Thy enormous benefits towards me.

[123] The 1550 edition contains a much briefer paragraph here than this one first appearing in 1554.

[124] "ob experientiae facilitatem."

[125] "et ab his quibus constat demonstratio."

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